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ECONOMIC ANALYSIS OF INVESTMENT AND REGULATORY DECISIONS--A GUI--ETC(U)
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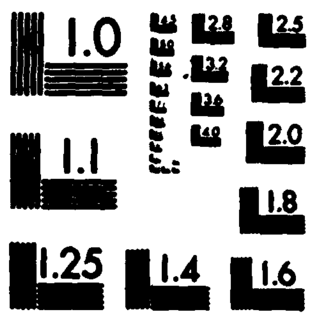

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16. Abstract

Every entity, whether public or private, is confronted with the economic problem: it wishes to accomplish more objectives than its resources will permit. This problem requires that two fundamental economic questions be answered: (1) what objectives should be pursued, and (2) how should these objectives be accomplished. In general, the answer to the first question is that an objective should be undertaken only when the value to be derived from undertaking it equals or exceeds what must be foregone to achieve it--its cost. The general answer to the second question is that each objective undertaken should be accomplished for the least amount of resources possible--or for the lowest cost.

Economic analysis provides a systematic approach to answering the economic questions. This Handbook presents methodology for applying economic analysis to problems commonly encountered by the Federal Aviation Administration. Techniques are developed for measuring such benefits as improved safety, delay reductions, cost savings as well as others. Cost estimation methodology is also presented.

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CHAPTER 1

INTRODUCTION

I. Purpose Of Economic Analysis

Two major Federal Aviation Administration (FAA) programs are: (1) provision of air traffic navigation and control services to the flying public, and (2) establishment and enforcement of regulations to ensure safe and efficient operation of the national aviation system (NAS). Programs under the first category involve the construction, maintenance, and operation of the NAS. These programs require the FAA to make major decisions regarding the allocation of public and private resources. Such decisions involve system acquisitions to provide new services, extend already provided services to new locations, and improve internal operating efficiency. Efficiently making these decisions is a major task of FAA management.

Programs under the second category encompass the making and enforcement of rules, regulations, and minimum standards pertaining to the manufacture, operation, and maintenance of civil aircraft. These activities include the certification of new aircraft, oversight of the existing fleet regarding maintenance and operating problems, and certification of pilots, mechanics, and others with respect to proficiency and medical fitness. Many of these regulatory activities impose substantial costs in that they mandate the allocation of private resources to specific uses. Efficient regulations require that these costs be carefully weighed against the benefits they are expected to achieve.

The problem of resource allocation confronts both agency managers and regulators. The purpose of economic analysis is to provide such decisionmakers with a systematic approach to making resource allocation decisions leading to the undertaking of appropriate objectives in a least cost manner. Such analysis is specifically mandated with respect to both investments and regulatory actions by Executive Orders, Office of Management and Budget Circulars, DOT Orders, and FAA Orders. (See Appendix A for an annotated list of relevant documents.) This handbook provides a guide to this process.

II. The Economic Questions

Every entity is confronted with the economic problem: it wishes to accomplish more objectives than its resources will permit. Economics, narrowly defined, is the study and analysis of how entities may maximize the attainment of their objectives subject to the limited resources available to be utilized in pursuing these objectives. This involves the simultaneous answering of two fundamental questions:

1) Which objectives should be pursued?
2) How should these objectives be accomplished?

In general, the answer to the first question is that an objective should be undertaken only when the value to be derived from achieving it equals or exceeds what must be foregone to achieve it—its cost. The general answer

to the second question is that each objective undertaken should be accomplished for the least amount of resources possible—or for the lowest cost. This will assure that the greatest number of objectives can be achieved for the available resources.

In the private sector, economic analysis can help provide answers to these questions. Market research can make decisionmakers aware of what goods and services consumers wish produced. Operations research and cost accounting methods can help assure that production is achieved at the lowest cost possible. Market forces will also aid decisionmakers in answering these questions before goods and services are produced. By producing only those goods and services which consumers are expected to buy, the question of what to produce is answered. In the quest to expand sales and increase profits, the lowest cost methods of production will be sought out. Market forces will also come to bear after production has occurred. Those who answered the economic questions correctly will be rewarded. Those who answered them incorrectly will be penalized. And those who answered them incorrectly and who continue to answer them incorrectly will be driven out of business. Thus, in the private sector correct answers to the economic questions will occur. 1/

1/ This, of course, assumes that the private sector markets are approximately competitive and that externalities—impacts on parties other than buyers or sellers—are not a significant consideration. Where the actual situation does not approximate competition and/or externalities exist, the correct answer to the economic questions will not necessarily occur.

In the public sector, the situation is somewhat different. Few governmentally produced goods and services are sold in the marketplace. Of those that are sold, the price is often arbitrary and does not reflect the cost of providing the good or service. Accordingly, in the absence of market forces, there is no assurance that production is carried out at the lowest cost possible. As a result of the lack of market direction in answering the economic questions, these answers can be provided only by economic analysis. Such analysis will indicate what goods are worth producing and how they can be produced as cheaply as possible.

A second difference between the private and public sector is that consumers of privately produced goods and services usually pay for them themselves, whereas consumers of publicly produced goods and services usually do not. This factor does not affect the need to answer the economic questions correctly. Regardless of who pays for a good or service, it should be produced only where the value placed upon it by its consumers equals or exceeds the cost of producing it. Where value exceeds production cost, the aggregate value of all production will increase because more value will be generated by the good or service to be produced than must be given up to produce it. Such cases will have the characteristic that consumers of the good or service which was paid for by someone else would be able, if required, to reimburse completely those who paid for it and still be better off than before. Similarly, who receives a governmentally produced good or service and who pays for it does not change the requirement that production be accomplished at the lowest possible cost. The more efficiently inputs are transformed into outputs, the more outputs that can be produced.

III. Handbook Organization

The remainder of this handbook contains six chapters and three appendices. An overview of economic analysis and the procedures required to evaluate investments and regulations is contained in Chapter 2. Chapters 3 and 4 provide the conceptual framework for measuring and valuing benefits and costs. They also present practical guidance for estimating benefits and costs in situations which are typical of FAA investments and regulations. Multi-period economic decision criteria are developed in Chapter 5. Topics included are why discounting must be used to compare benefits or costs occurring in different future time periods, how to use discounting, and how to make decisions between alternatives which extend over a number of time periods. Chapter 6 deals with sensitivity analysis. It presents techniques to aid decisionmakers in selecting between alternatives under conditions of risk and uncertainty. Techniques for measuring price level changes for specific goods or services as well as for the general price level are contained in Chapter 7. This chapter also sets out the appropriate treatment for inflation in benefit-cost analyses.

Appendix A contains a listing, accompanied by a brief explanation, of the Executive Orders, Office of Management and Budget Circulars, DOT Orders, and FAA Orders which document the requirement for economic analysis. Appendix B briefly summarizes <u>Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs</u>. It contains

estimates for critical values—such as the value of a statistical life, the value of passenger time, and the operating cost of various aircraft—which are required for economic analysis. Finally, Appendix C contains tables of factors useful in making the present value calculations detailed in Chapter 5.

CHAPTER 2

ECONOMIC ANALYSIS—AN OVERVIEW

I. General Types of Economic Analysis

The term economic analysis is a broad one. It encompasses a spectrum of topics including economy-wide analysis, regional studies, market structure investigations, and analysis of specific decisions. It is this last topic, as applied to FAA investment and regulatory decisions, that is the topic of this handbook. Such applications usually concern the addition or subtraction of a particular investment or regulation to the existing system or body of regulations—denoted as marginal or incremental analysis. For the most part, the methodology outlined is also applicable to the evaluation of a system in total or a body of regulations.

Economic analysis of investment and regulatory decisions seeks to provide answers to two economic questions: (1) is a particular objective worth achieving, and (2) which of several alternative methods of achieving an objective is best? Two general procedures are employed to answer the questions. The first, cost effectiveness analysis, assumes that the first economic question has been answered in the affirmative and concentrates on providing an answer to the second question of which alternative is best. The second, benefit-cost analysis, seeks to answer both questions. While benefit-cost analysis is more complete than cost-effectiveness analysis, studies are often limited to the latter because of an inability to measure benefits in dollars.

A. Cost-Effectiveness Analysis

There are two types of cost-effectiveness analysis: (1) least cost studies, and (2) constant cost studies. Least cost studies are appropriate where the level of effort is undetermined and relatively unconstrained but the level of output/benefits is fixed. The procedure concentrates on identifying the least expensive way of producing a given amount of a certain output. The analysis typically begins with a statement of a required objective. Alternative methods of achieving the requirements are then defined. Costs are estimated for each alternative and the least cost alternative identified.

Least cost studies are frequently undertaken when the decision has already been made to produce a given amount of the output in question. Examples of such situations are when a requirement for the output is established by administrative or legislative direction, when the output is required to support another program which is required, or when deciding whether or not to replace existing equipment with new, cheaper-to-operate equipment which produces the same output. In all such situations, the analysis is confined to answering the question of how to produce.

Constant-cost studies are appropriate in situations where the level of output/benefits is undefined but the budget/resources available are fixed. The purpose of the analysis is to identify the outputs of each of a number of equal cost options and then decide which of the alternatives is best

for producing the determined level of outputs/benefits. Such a situation typically arises where an agency is allocated a given amount of funds and directed to pursue a particular objective. The analysis permits the agency to determine how to produce the maximum amount of desired output/benefits with the given funds.

Analyses of this type require that outputs be measured in some way. If only one output is involved, the measurement can be in any convenient albeit arbitrary unit. If more than one output is involved, a unit of measurement applicable to all units is required. If no such unit can be found, the study must of necessity be confined to a description of the outputs of the various alternatives. Judgments as to the relative importance of each separate output are then left to the policymaker.

B. Benefit-Cost Analysis

Benefit-cost analysis seeks to determine whether or not a certain output shall be produced and, if so, how best to produce it. It thus goes beyond the limited objective of cost-effectiveness analysis of determining how best to produce. Benefit-cost analysis calls for the examination of all costs related to the production and consumption of an output, whether the costs are borne by the producer, the consumer, or a third party. Similarly, the method requires an examination of all benefits resulting from the production and consumption of the output, regardless of who realizes the benefits. Because the ultimate objective of benefit-cost

analysis is the comparison of benefits and costs, they both must be evaluated in the same unit of measurement. It is rare that anything other than dollars proves to be satisfactory.

The benefit-cost procedure requires that alternative methods of producing the output be identified. The benefits of each alternative are then valued in dollars and compared to their expected costs. That alternative for which benefits exceed costs by the greatest amount is identified as the project alternative to be undertaken. The action is worth taking because benefits exceed costs. It is best because benefits exceed costs by the greatest amount. Unfortunately, such studies often break down in the identification and valuation of benefits. Governmentally produced outputs are usually not sold under market conditions making it difficult to determine their value to consumers and the benefits they may provide to the rest of society.

II. Economic Analysis Process

The economic analysis process consists of eight steps:

1. Define the Objective
2. Specify Assumptions
3. Identify Alternatives
4. Estimate Benefits and Costs
5. Describe Intangibles
6. Compare Benefits and Costs and Rank Alternatives
7. Perform Sensitivity Analysis
8. Make Recommendations

The analytical considerations involved in each of these steps are described as follows.

STEP 1 - DEFINE THE OBJECTIVE

This apparently obvious step is critical to a useful analysis. The analyst cannot proceed until the exact objectives of the project or regulation under consideration are precisely stated. Moreover, any project or regulation actually undertaken without a clear understanding of the desired outcome is likely to be inefficient and, perhaps, unnecessary. The objective should be stated in terms of desired outputs of the project or regulation. It is a common failing to describe an action in terms of the inputs required to accomplish it. For example, the objective of providing airspace surveillance should be stated in terms the expected improvement in benefits--inhanced safety, increased system capacity, reduced costs, better weather detection, etc.--rather than as a need to procure a new radar system.

In some situations the objective will be specified by external authority. For example, either the executive or legislature may mandate that a particular objective be pursued. The analyst's role in such a case is limited to formulating a succinct statement of the mandated objective and clarifying ambiguities that may be present in it.

At times, several projects or regulations may be combined for administrative purposes. For analytical purposes, they should be separated and independently evaluated to the extent that their objectives are functionally separate. Functionally separate objectives are those which are independent of each other and do not depend upon common investments or regulations. For example, regulations pertaining to design requirements of different types of aircraft should be considered separately. But regulations concerning flight time and duty time restrictions should be considered together because one interacts with the other. As to common investments, the separate objectives of safety and delay reduction should be considered together when they arise from a common investment such as an ILS and separately when they arise from separate investments such as a VASI (safety oriented) and RNAV (delay reduction oriented).

STEP 2 - SPECIFY ASSUMPTIONS

Analysis of projects and regulations which will have most of their impact in future years involves a substantial amount of uncertainty. In order to proceed, assumptions must frequently be made. These should be clearly identified and the estimate upon which they are based--judgment, econometric forecast, etc.--clearly elaborated. Assumption specification often cannot be done exhaustively as a second step. Frequently, some assumptions cannot be specified at the beginning of a project. Others must be changed as the project proceeds and more information is obtained or information gaps appear that can be filled only by assumption.

STEP 3 - IDENTIFY ALTERNATIVES

This is one of the most difficult yet important parts of a benefit-cost analysis. It involves the identification of all reasonable ways to achieve the desired objectives. This step is critical because only those alternatives that are identified will be evaluated. Any alternatives that exist but are not identified not only will not be evaluated, but, critically, will not be selected as the most efficient method to achieve the objective. This is critical because, if a sufficiently low cost alternative is not identified, the analysis that follows may determine that the objective is not worth undertaking since its costs exceed its benefits.

This step should not be interpreted to require that every conceivable alternative way of doing something needs to be included in the analysis. Many technically possible alternatives may be ruled out from the beginning as inferior to others which are being considered. This may occur in several situations. First, it may be well known that a particular approach is more costly than others, at least for the scale of activity under consideration. Second, it must be recognized that most investments or regulations build upon existing ones. Because new investments or regulations must mesh with existing ones, many potential alternatives which do not mesh can be ruled out. Note that this exclusion criterion is not applicable when considering the adoption of a new system or a functionally separate set of regulations or a replacement for existing ones. Finally, other cases may arise where it can be determined that one or more

alternatives are inferior to the others before a formal analysis is undertaken. The analyst is cautioned that such determinations should be well founded and supportable. Moreover, while such exclusions will save analytical resources, care must be taken that viable alternatives--perhaps the best one--are not excluded at this point. In particular, the analyst must not exlude alternatives merely because a predisposition exists in favor of others arising out of causes such as past practice or external constraints such as budget or personnel ceilings.

Successful alternative identification requires extensive knowledge of the production process or processes which can be utilized to achieve the objective. Such information is often highly technical and not confined to any single area of expertise. As a result, it is often necessary to enlist the aid of one or more technical experts at this stage of the analysis.

STEP 4 - ESTIMATE BENEFITS AND COSTS

This step requires that the value in dollars of all quantifiable benefits and costs be estimated. With respect to benefits, it is first necessary to determine the goods and services which the project or regulation can be expected to yield. Then, the value of these goods and services must be determined. For costs, the physical resources which the project or regulation will consume must be determined and their costs estimated. Guidelines for formulating benefit estimates are presented in Chapter 3. Procedures for cost estimation are contained in Chapter 4.

STEP 5 - DESCRIBE INTANGIBLES

A natural follow-on to quantification of benefits and costs is the identification and description of intangibles--those things which cannot be evaluated in dollar terms. Intangible considerations should be listed and described for the decisionmaker. If possible, a range in which a dollar value could be reasonably expected to fall should be reported. Intangibles should not be neglected; it is very likely that they will be extremely important to the outcome of the analysis.

STEP 6 - COMPARE BENEFITS AND COSTS AND RANK ALTERNATIVES

It is this step that provides answers to the economic questions of what objectives to pursue and how most efficiently to obtain them. It establishes whether or not benefits exceed costs for any or all of the alternatives, thus indicating whether or not the objective should be undertaken. In addition, by providing a ranking of the alternatives it identifies which is the most efficient in achieving the objective. Criteria for making this comparison are enumerated in Chapter 5.

STEP 7 - PERFORM SENSITIVITY ANALYSIS

Because uncertainties are always present in the benefit and cost estimates used in the comparison of alternatives of STEP 6, a complete picture of the situation can be presented only if key assumptions are allowed to vary. When this is done, it is possible to examine how the ranking of the

alternatives under consideration holds up to a change in a relevant assumption and under what conditions the project is or is not worth doing. Methodology for conducting sensitivity analysis is presented in Chapter 6.

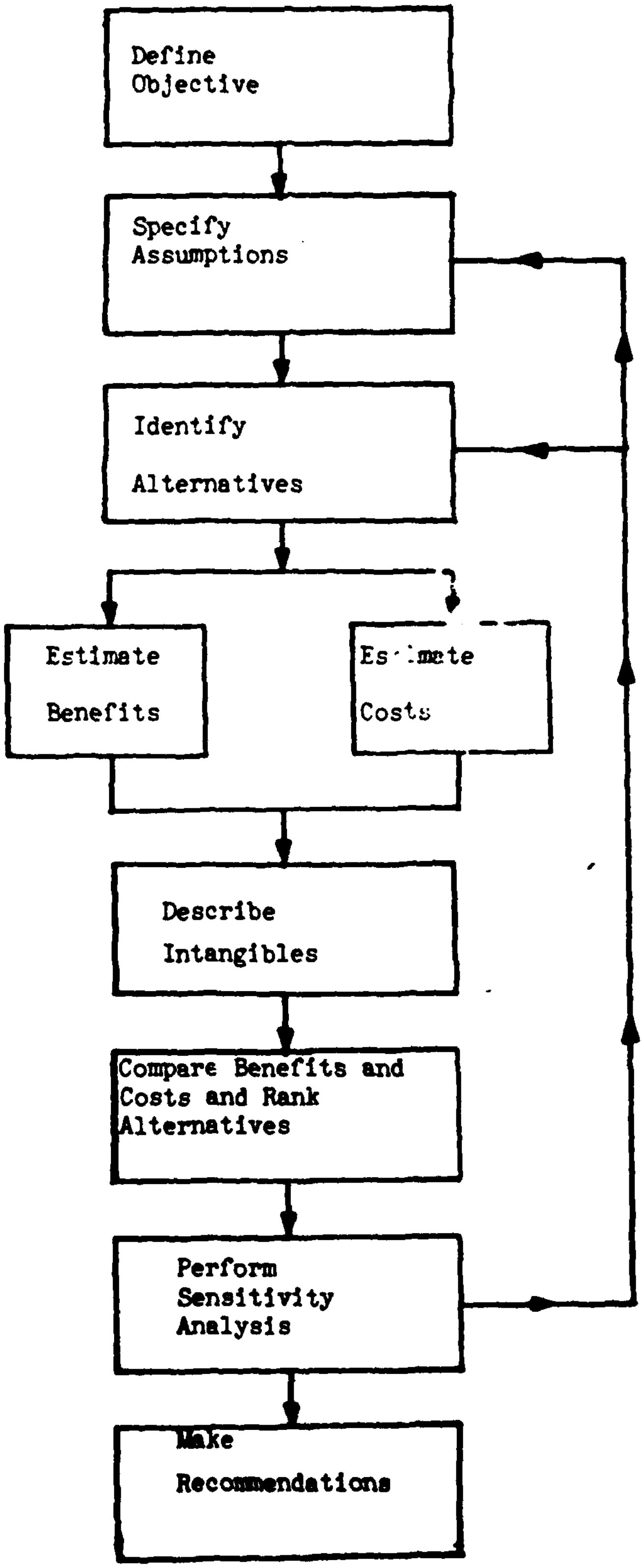
In addition to helping deal with uncertainty, sensitivity analysis also provides feedback within the economic analysis process. At this stage of the analysis, it is often necessary to change key assumptions, formulate additional alternatives, and/or revise methodology. The analysis is then repeated under these new conditions. Thus, the economic analysis process becomes an iterative one.

STEP 8 - MAKE RECOMMENDATIONS

The final outcome of the economic analysis process is a recommendation concerning the proposed objective. Under a benefit-cost analysis there are two parts to this recommendation: should the activity be undertaken, and if so, which alternative should be selected to achieve it. For a cost-effectiveness analysis, one of two answers is provided: which alternative should be selected to achieve the objective or on what activities should the available resources (e.g., budget) be expended so as to best achieve the stated objectives. Note that this step goes beyond STEP 6 in that it incorporates not only a comparison of alternatives but also information gained by the sensitivity analysis and the iterative process. The entire economic analysis process is summarized in Figure 2-1.

Figure 2-1

ECONOMIC ANALYSIS PROCESS



CHAPTER 3

BENEFIT ESTIMATION

I. General

Benefits are the outputs of goods or services that are produced by the operations and regulations of a government agency. Most frequently they are provided to the public but may on occasion be furnished to other governmental agencies. When valued in dollars, benefits are analogous to private sector revenues. However, unlike the private sector where products are sold and their value established in the market place, most governmental outputs are provided free or at arbitrary prices. As a consequence of these factors, measurement of benefits can be a formidable task.

A related outcome of government operations or regulations are cost savings. Strictly speaking, they are not benefits because they do not represent products or services delivered to the consumer. Rather, they are reductions in the cost of delivering other products or services. Nonetheless, they should be treated as benefits because they represent value to the government and/or private parties which arises as the result of undertaking a project or regulation and incurring its life cycle cost.

The benefit estimation procedure is a three step process. The first step is to identify what effects will occur and who will be affected as a consequence of undertaking an activity. This can be difficult in itself if the proposed activity is large and/or complex. The second step is to measure these effects in physical units. Finally, the physical units must be valued in dollars. Suggested procedures for accomplishing these tasks are detailed in Section III. A theoretical basis for valuation is considered in Section II.

II. Benefit Valuation

A. A Concept of Value

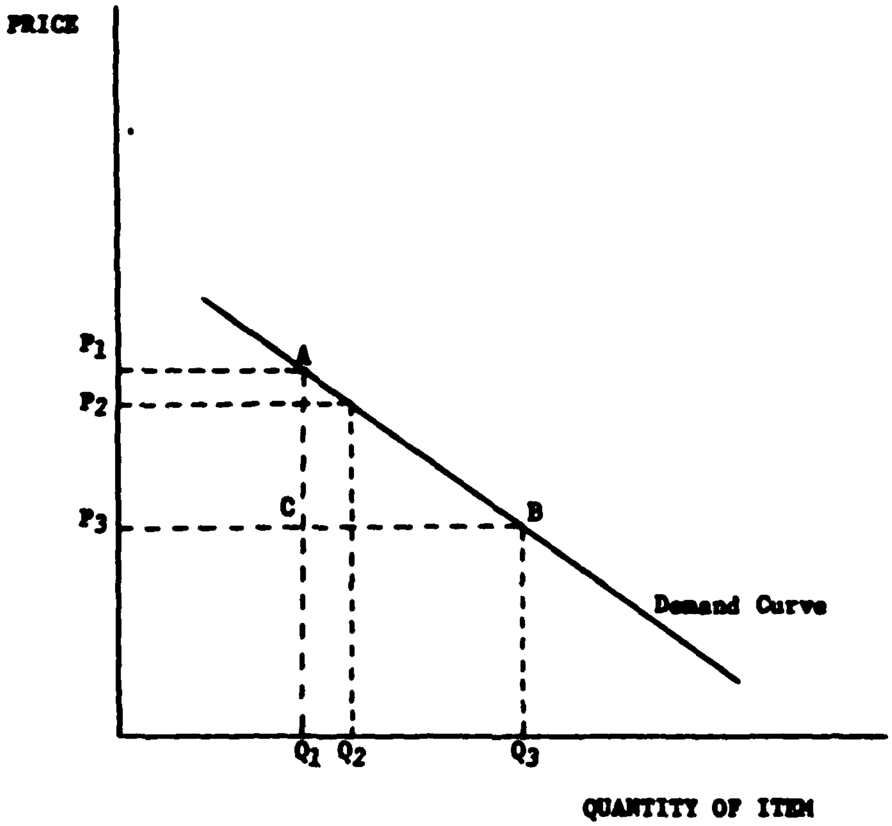
Before beginning a discussion of how to value specific benefits, it is important to know what is meant by value and how it can be measured. In this disc..sion a principal distinction lies between the value of a product to consumers and the amount of money they must spend to acquire the product. Money is a generalized commodity which can be transformed into other specific commodities through exchange. When a consumer voluntarily exchanges money for a specific commodity, the consumer indicates that the value placed on the specific commodity equals or exceeds the value placed on what that amount of money could buy in its next most valued use. If it did not, the consumer would not voluntarily make such an exchange. The amount of money expended on a commodity is a minimum measure of the value of a commodity to a consumer. The total

value of a commodity is measured by the maximum amount of money a consumer would be willing to give up and still be willing to voluntarily engage in the exchange. The concept of value measurement may be clarified with reference to the economist's concept of the demand curve.

Figure 3-1 presents a typical demand curve for a particular commodity. The curve indicates the quantity of the commodity that consumers as a whole will purchase at any particular price. It slopes downward to the right because consumers can be expected to purchase larger quantities at lower prices than at higher ones. A useful property of the demand curve is that it traces out the prices which consumers are just willing to pay for an additional unit of a commodity for all different quantities actually purchased. This price represents the marginal value placed by consumers on an additional unit of the commodity. In Figure 3-1, the demand curve shows that consumers can be expected to buy quantity Q_1 at price P_1. To induce consumers to increase purchases by one unit to Q_2, price must fall to P_2. Thus, the maximum price that will be paid for one more unit, provided that Q_1 units are currently being purchased, is P_2. Or in other words, P_2 is the marginal valuation which consumers place on this unit of the commodity. To determine the marginal value of each successive unit, it is necessary to repeat the process. The total value to the consumers of a number of units is obtained by summing the marginal valuations. In Figure 3-1, the sum of the marginal valuations of units $Q_3 - Q_1$ is represented by the area Q_1ABQ_3. This area represents the maximum amount consumers would be

FIGURE 3-1

TYPICAL DEMAND CURVE



willing to pay for units $Q_3 - Q_1$. It consists of rectangle Q_1CBQ_3 plus triangle ACB. Rectangle Q_1CBQ_3, equal to $P_3 \times (Q_3 - Q_1)$, equals the total amount consumers would be required to pay for $Q_3 - Q_1$ at P_3.

Triangle ACB represents additional value of the units $Q_3 - Q_1$ over and above this payment which consumers would be willing to pay rather than go without these units of the commodity. 1/

B. Benefits of FAA Actions

Most FAA investment projects and regulatory actions are intended to reduce the costs of air transportation. Cost reductions accrue to the flying public through reduced accident costs, reduced delay costs, and in other ways. To the extent that FAA activities result in relatively small cost reductions, the benefits of such activities may be valued based on current system use without taking into account any increase in system usage resulting from cost reductions. With reference to Figure 3-1, assume that an FAA action causes the per unit cost of using some segment of the system to fall from P_1 to P_2. The value of this action to the

1/ The above discussion does not indicate the need to measure triangle ACB under a demand curve adjusted for income and other factors. While this is theoretically incorrect, the practical impact of making the appropriate adjustments would be insignificant for FAA activities. For an introductory discussion of such problems, see Mark Blang, Economic Theory in Retrospect, Richard D. Irwin, Inc., Homewood Illinois, 1968, pp. 359-373.

current users of the service may be approximated by $(P_1 - P_2) \times Q_1$. Although this procedure understates the true increase in value by ignoring the value of unit $Q_2 - Q_1$, the amount of error is small enough that it can be ignored for practical purposes.

For activities that result in larger cost reductions to the public, the value of additional units which will be demanded must be considered or the total increase in value will be substantially understated. In terms of Figure 3-1, if costs are reduced from P_1 to P_3, consumers of Q_1 units will be benefited by $(P_1 - P_3) \times Q_1$. But the reduction of $P_1 - P_3$ will also induce the additional units of $Q_3 - Q_1$ to be demanded, both by current and new consumers. The value of these units is equal to the sum of their marginal valuations as indicated by area Q_1ABQ_3. The magnitude of the cost reduction makes this amount large enough that it can no longer be ignored.

Frequently, the value of additional units such as $Q_3 - Q_1$ are measured net of the costs which consumers must bear to consume them. The resulting net benefit is then compared to other public and private costs in the benefit cost analysis. In Figure 3-1, the net benefit would be represented by triangle ACB under this procedure. This is equal to the sum of the marginal valuations, Q_1ABQ_3, less the amount consumers are required to pay, as shown by rectangle Q_1CBQ_3. (Note, this procedure is strictly a convention. The same result would occur if total benefits of units $Q_3 - Q_1$, Q_1ABQ_3, were counted under benefits and consumer borne costs, Q_1CBQ_3, considered under costs in Chapter 4.)

The total net benefit of a project is equal to the sum of the benefits to current consumers plus that associated with the additional units demanded because of lower costs. In Figure 3-1, this amount is indicated by area P_1ABP_3.

For commodities traded in markets, value may be determined with reference to observed market behavior of consumers. For many items produced by government or brought about by government regulation, value cannot be determined by reference to market behavior because the items are not traded in markets. Rather, they are provided free or at arbitrary prices. Nonetheless, they may be valued by determining the maximum amount consumers would be willing to pay for them. The following section outlines methodology for estimating the value of benefits provided by FAA investment and regulatory activities.

III. Benefit Categories

There are three primary areas in which FAA investments and regulations generate benefits. These are safety improvement, capacity increases and delay reductions, and cost savings. Other benefits outside of these three areas also frequently occur and should be included in any particular analysis using appropriate methodology for the particular circumstance. Each of these benefit areas is now considered.

A. Safety

Safety may be defined in terms of the risk of death, personal injury, and property damage which results from air transportation accidents. A major responsibility of FAA is to reduce such occurrences. FAA carries out this function through its capital investment, operations, and regulatory functions. The evaluation of the benefits of such activities requires that we determine the extent to which deaths, injuries, and property damage resulting from preventable accidents will be reduced, and that these reductions be valued in dollars. This subsection presents methodology for determining deaths, injuries, and damages prevented by risk reduction. Once known, these can be valued in dollars by applying standardized FAA critical values (See Appendix B).

1. Unit of Exposure

Meaningful accident measurement requires that accidents be stated as a rate per some unit of exposure. Such a unit should have the characteristic that each time it occurs an accident of a particular type either can or cannot result. The appropriate unit of exposure will differ depending on the type of accident under consideration. Every aircraft movement from one point to another consists of several components: departure taxi, take off, climb out, the enroute phase, descent, approach, landing, and arrival taxi. All components other than the enroute phase will have approximately the same duration each time they

occur and will be approximately independent of the duration of the enroute component. Moreover, each component other than the enroute one constitutes a self contained phase of flight which is approximately the same from one flight to another and which must be undertaken each and every time an aircraft is moved from one place to another. Accordingly, because the risk of an accident can be considered to be approximately independent of the duration of a flight for all but the enroute component, the appropriate measure of exposure for other than enroute accidents should not vary with the duration of a flight.

For the enroute component of a flight, the opportunity for an accident to occur is present throughout the duration of the enroute component. The longer the enroute component lasts, the greater the exposure to the risk. Consequently, appropriate exposure measures for the enroute component should vary with the duration of the flight. In the case of enroute turbulence accidents, the exposure measure should also vary with the number of passengers transported. This is because the chance that at least one passenger's seat belt will be unfastened at the same time an aircraft encounters turbulence, thus creating an opportunity for a turbulence accident, varies with the number of passengers as well as with the duration of the flight.

For the most part, all flight segments except the enroute one occur primarily in the terminal area. Acceptable exposure measures are operations and instrument operations. [2/] An operation occurs each time

2/ Air Traffic Activity, Federal Aviation Administration, published annually.

an aircraft either takes off or lands. An instrument operation occurs each time an aircraft on an instrument flight plan takes off or lands. A third measure, annual instrument approaches, occurs each time an aircraft on an instrument flight plan makes an instrument approach under instrument weather conditions. Although conceptually acceptable and used in many previous analyses, it is not recommended that this measure continue to be used. It is subject to substantial measurement errors and may not continue to be compiled by the agency.

For accidents which occur enroute such as those resulting from engine failure or flight system failure, exposure measures related to flight duration are appropriate. Acceptable measures are hours flown or miles flown. Measures which also reflect the number of passengers carried such as passenger miles, the product of miles flown and passengers carried, should not be used because the risk of these types of enroute accidents is not dependent on the number of passengers being carried. For enroute turbulence accidents, measures such as passenger miles are acceptable.[3/]

2. Models

One method of determining prevented deaths, injuries and property damage is to construct a model which relates these items to a unit of exposure. Such a model typically computes the number of accidents that can be

3/ CAB Air Carrier Traffic Statistics, published monthly, and FAA Statistical Handbook of Aviation, published annually.

expected to occur per unit of exposure both with and without a particular system in place. The difference is the number of prevented accidents. The actual estimating procedure can be as simple as calculating accidents as a fraction of the exposure unit. Or it can be complex, allowing the probability of an accident to vary with a host of other factors such as weather, aircraft types, length of runway, etc.

Prevented deaths, injuries, and property damage can then be ascribed to the prevented accidents using historical averages for these types of accidents for fatalities, minor and serious injuries, and damage per accident. Because there is wide variation in fatalities, injuries and property damage by type and size of aircraft as well as by passenger loads, it is important that the averages used reflect the aircraft types and passenger loads likely to have been involved in the prevented accidents. This can be accomplished by using different averages for different airports or air routes.

A comprehensive model for estimating safety and other benefits for approach and landing aids is the "Approach Aid Establishment Criteria Model." The model computes the benefits and costs of establishing and/or decommissioning any of the following aids, either singularly or in combinations: VASI, NDB, VOR, VOR/DME, LOC, LOC/DME, ILS, ILS/DME. Accompanying the model is a data base containing most of the data required to run the model for 3338 runways. This greatly facilitates

model use because only a relatively few parameters need be input to use the model. [4/]

3. Judgmental Accident Evaluation

A second method for determining prevented accidents is to examine a large number of accidents of a particular type and make a judgmental determination of which ones could have been prevented by the investment or regulation in question and which ones could not have been. To add validity to the work, it is often desirable to have the analysis of accidents undertaken by a group of knowledgeable individuals so as to avoid the biases of any one particular person. In those cases where a decision between classifying an accident as preventable or not preventable is a toss-up, it is classified as preventable by convention. This is done to let the benefits of any doubt favor making the investment or implementing the regulation.

The judgmental method has the advantage of simplicity and ease. Moreover, it does not have the large data requirements typically associated with model estimation. It has the disadvantage of almost always overstating the benefits of any proposed activity. This occurs because some accidents judged preventable would still have occurred. A given safety program will be successful in preventing only a certain

4/ Approach Aid Establishment Criteria Model Users Manual, draft report, Federal Aviation Administration, April 1981.

percentage of all potentially preventable accidents. This percentage is generally unknown. Note, however, that a proposed activity which fails to muster benefits in excess of costs when the judgmental method is used is probably not worth undertaking.

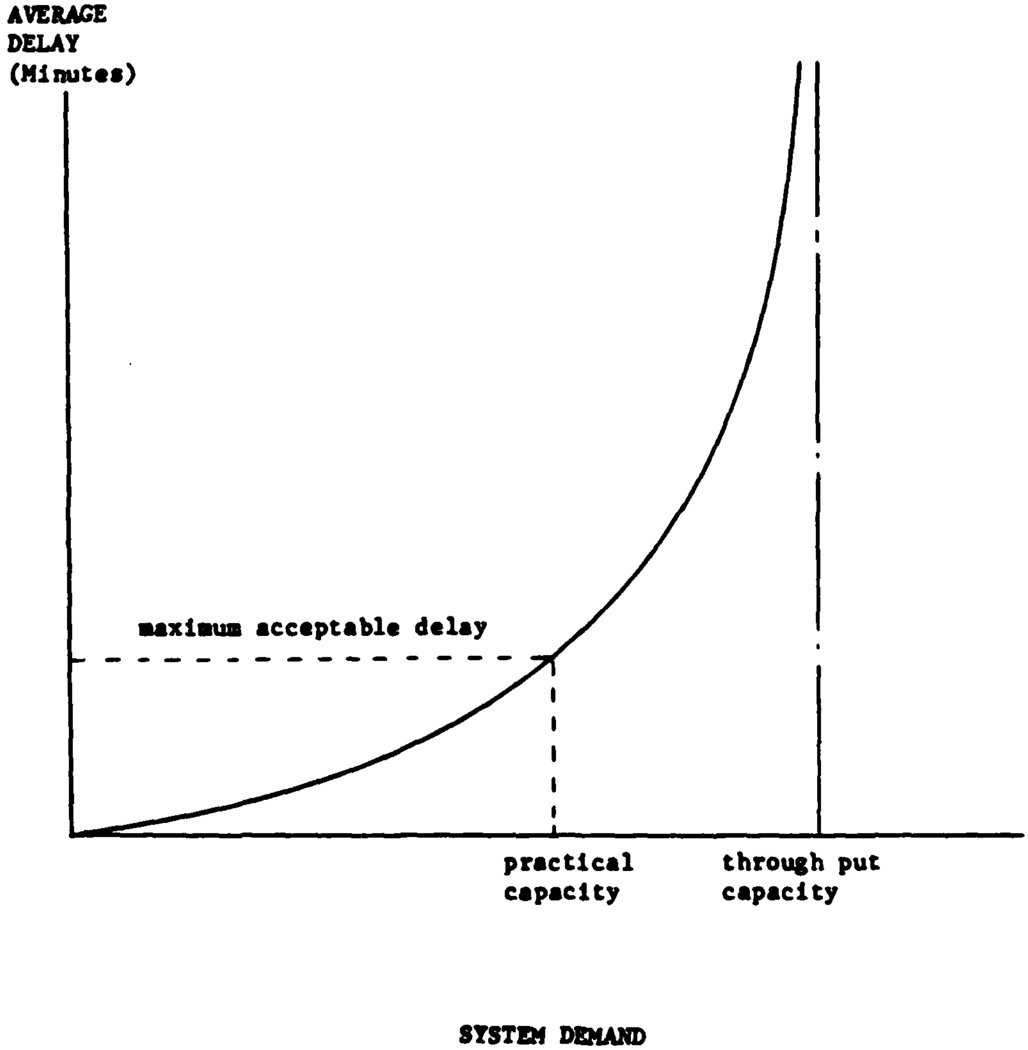
B. Capacity Increases and Delay Reduction

The major reason for operating the air traffic control system is to allow many aircraft to use the same airspace simultaneously without colliding with one another. The capacity of the ATC system to handle aircraft safely is a given for any particular weather situation. As this level is approached, some aircraft must wait to use the system or various parts of it until they can be accommodated. This waiting imposes costs both in terms of aircraft operating expenses and the value of wasted passengers' time. Estimation of the delay benefits of a new project or regulation requires that we measure the aggregate annual aircraft operating time and passenger time which the new proposal will save. This saving is the difference between the delays currently experienced and those which would be experienced with the proposed new project or regulation. Once determined, the value of this saved time can be valued in dollars using the values provided in Appendix B.

The estimation of delay reductions that a particular proposed project or regulation can be expected to produce requires that the relationship between average delay, capacity, and system demand for the segment of the

FIGURE 3-2

RELATIONSHIP BETWEEN CAPACITY
AND AVERAGE DELAY

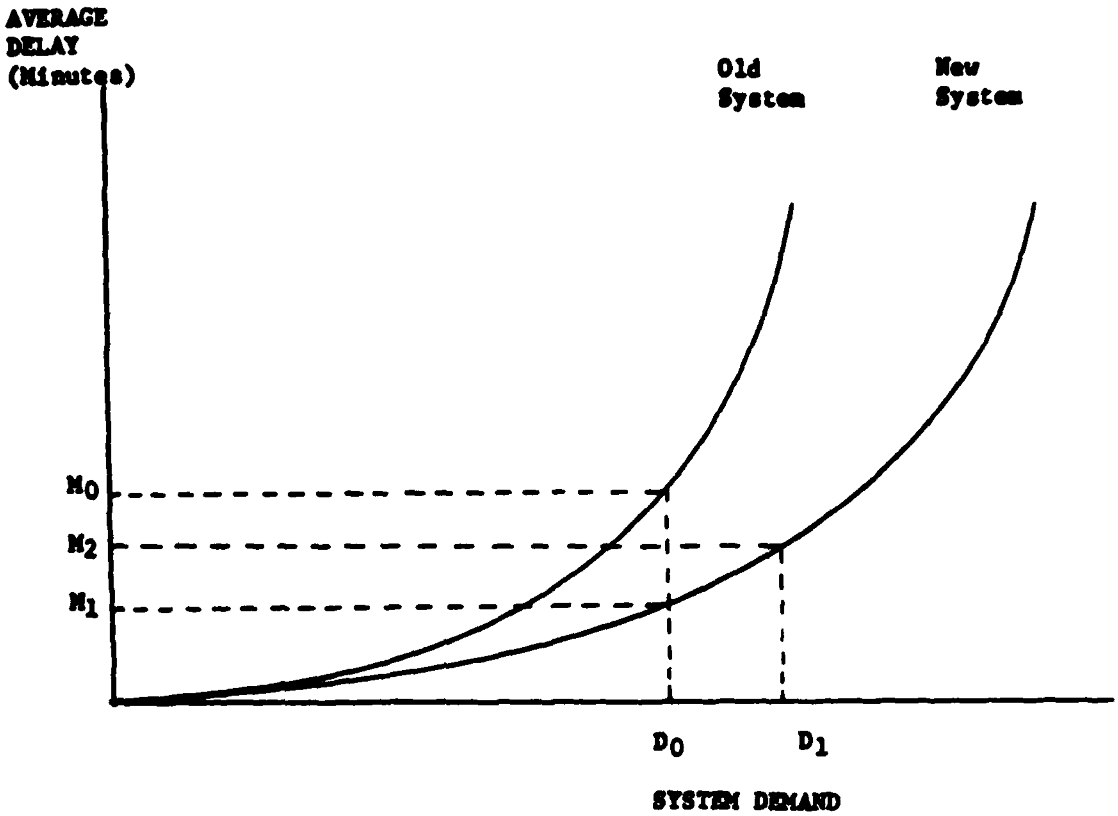


ATC system of interest be determined for both the existing system and the proposed new one. Although such relationships will differ from situation to situation, their general form is depicted in Figure 3-2. As indicated, two definitions of capacity are relevant in defining this relationship. One is the "through put" measure. It defines the absolute number of system users that can be served in a given period of time, provided that a user is always present waiting to use the system. The second measure is that of "practical" capacity. It provides a measure of the ability of a given system to accommodate users subject to some maximum acceptable level of delay. As shown, average delay is low at low levels of demand and increases as demand approaches capacity, as defined under either definition. As demand exceeds "practical" capacity, delay exceeds the acceptable level. And as demand pushes up against "through put" capacity, delays begin to become infinite. This occurs because the number of users demanding service, per time period, begins to become greater than the ability of the system to serve them, resulting in an ever growing line of users waiting for service.

It is important to note that delays began to occur before capacity is reached. This happens because of the random nature in which system users demand services. If all users of a system consistently arrived at evenly spaced intervals, the system could provide service hourly to a number of users equal to the "through put" capacity rate. No delay would occur until "through put" capacity was actually exceeded. In actuality, system

FIGURE 3-3

DELAY REDUCTION MEASUREMENT



users do not arrive consistently at evenly spaced intervals. Sometimes several users arrive at one time and sometimes no one arrives. As a consequence, some of those who arrive at the same time as do others must be delayed.

Measurement of capacity and delay benefits requires that the relationship depicted in Figure 3-2 be determined for both the existing system and the proposed new one. The general form of such relationships is shown in Figure 3-3. Each has the same general form as that of Figure 3-2, but with the proposed new system having greater capacity and lower average delays than the old one at each level of demand.

The average delay reduction per system user at the current level of demand, D_0, is $M_1 - M_0$ minutes. This is not the delay reduction that will occur if the indicated capacity increase is provided at demand level D_1 after system users have adjusted to the increase, however. Capacity improvements will reduce the costs of using the system both in terms of passenger time and aircraft operating expense. As indicated in Figure 3-1, cost reductions will generally lead to an increase in the quantity of any good or service demanded. In this particular case, assume system demand increases from D_0 to D_1 resulting in delay of M_2 per user. This level of delay is above M_1 and represents that level which will result from the indicated increase in capacity once demand has adjusted to the lower costs brought about by the capacity increase.

Having determined the average delay per system user after demand adjustments, it is now necessary to value these delay reductions. For users of the system before the capacity improvement, valuation is given by total cost savings per user. Because most delay reduction activities are air terminal area related, it is convenient to define user as an operation for the remainder of this discussion. The value of delay reduction for that level of operations that was occurring before the capacity improvement is equal to $M_0 - M_2$ minutes multiplied by the operating cost of the aircraft plus $M_0 - M_2$ minutes multiplied by the average number of passengers per aircraft and the value of passenger time. The value of passenger time and aircraft operating costs is given in Appendix B. The average number of passengers per aircraft must be determined by the analyst in each specific case.

For operations induced by the lower costs per user brought about by the capacity increase, value will be less because each additional unit of a commodity is valued less by consumers, as explained in Section II of this chapter. Value is given by the change in benefits accruing to passengers and air transportation service providers less the additional costs required to produce these benefits. Under conditions of competition in the air transportation industry, it can be shown that these net benefits can be approximated by one half of the number of additional operations, $D_1 - D_0$ in Figure 3-3, multiplied by $M_0 - M_2$ minutes multiplied by the operating cost of the aircraft plus one half of the number of operations, $D_1 - D_0$, multiplied by $M_0 - M_2$ minutes multiplied by

the average number of passengers per aircraft multiplied by the value of passenger time.[5/] Total delay benefits are equal to this amount plus the benefits for those operations already being conducted before the capacity increase.

Finally, it should be noted that the above methodology must be applied to each time period over the life of the capacity improvement. This requires that values for system demand be estimated for each year assuming both that the capacity improvement is and is not put in place. In terms of Figure 3-3, both D_0 and D_1 must be estimated for each year of the improvement's economic life. Demand values assuming the improvement is not in place are given by the actual value for the current year and by forecasted values for future years. Demand values assuming the improvement is adopted can be computed by marking up the actual or forecasted values by an appropriate factor.

5/ This procedure is an approximation for several reasons. First, it assumes, correctly or not, that demand curves can be represented as straight lines over the relevant range of interest. Second, it assumes that all passengers can be represented by a single "representative passenger." Finally, implicit in the procedure is the assumption that passengers of various types at various airports increase their system usage in response to a reduction in delay by the same proportion. A detailed discussion of the limitations of this procedure as well as attempts to improve upon it are contained in Robert A. Rogers, John L. Moore, and Vincent J. Drago, Impacts of UG3RD Implementation on Runway System Delay and Passenger Capacity, Final Technical Report, Department of Transportation, March 31, 1976.

An appropriate mark-up factor is given by the product of the total demand elasticity [6/] for air transportation and the percentage change in cost, both in passenger time and aircraft operating cost, implied by the capacity improvement. [7/] The total demand elasticity for air travel has been estimated by DeVaney [8/] to be about 1.5. The percentage change in cost may be calculated by taking the ratio of total cost per passenger of an average air trip after and before the capacity improvement and subtracting unity.

Per passenger cost before the improvement is equal to the sum of average trip time multiplied by hourly aircraft operating cost divided by the average number of passengers per aircraft and average trip time plus 50 minutes multiplied by the value of passenger time. (The 50 minutes represents passenger ground time assumed by DeVaney and implicit in his elasticity estimate.) Cost after the improvement is given by the same procedure, only with the average trip time reduced by the time saved by the capacity improvement.

6/ Total demand Elasticity is defined as the percentage change in quantity demanded divided by the percentage change in total price, where total price is defined as the dollar cost of a commodity plus the value of the time required to consume it. For an introductory discussion of the concept of elasticity, see Paul A. Samuelson, Economics, ninth edition, McGraw-Hill Book Company, Inc., New York, 1973, pp. 379-385.

7/ Strictly speaking, the mark-up factor equals the percentage change in airline fare or price to the consumer plus the percentage change in passenger time cost. However, under conditions of competition it can be expected that operating cost savings will be passed through to consumers so that percentage changes in operating cost closely approximate percentage changes in fares.

8/ Arthur DeVaney, "The Revealed Value of Time in Air Travel," Review of Economics and Statistics, February 1974.

The actual estimation of delay reduction usually requires the use of a model. A host of different such models exist, each pertaining to a particular segment of the ATC system and each with its own strengths and weaknesses. [9] Depending on the particular situation and proposed project or regulation, the analyst must choose or develop an appropriate model. An important factor in selecting or developing a suitable model is the segment of the ATC system in which delays occur and/or are caused.

Delay is commonly classified by the segment of airspace with which it is associated. This leads to confusion as to where aircraft actually experience delay and as to where the events that cause the delay occur. Information concerning the airspace segment where the factors which cause delay occur is important in that it focuses attention on segments of airspace with insufficient capacity. Knowledge of where the delays actually are experienced is important in that it identifies where the delayed aircraft must actually be accommodated and where delay costs occur. Moreover, since some agency delay programs, such as "flow control," seek to move delays from one air route segment to another, such information is essential if these programs are to be evaluated.

Figure 3-4 presents a matrix of delay classifications which indicates where delay originates and where it actually occurs. Airspace segments where delay originates are listed across the top. Airspace segments

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9/ A useful guide to these is A. R. Odoni and R. W. Simpson, Review and Evaluation of National Airspace System Models, Report No. FAA-EM-79-12, Department of Transportation, October 1979.

FIGURE 3-4

DELAY CLASSIFICATIONS

Location Delay Experienced	Airspace Where Delay Caused			
	Departure--Terminal (I)	Enroute (CONUS) (II)	Enroute (Oceanic) (III)	Arrival--Terminal (IV)
A. Departure Terminal	IA	IIA	IIIA	IVA
B. Enroute		IIB	IIIB	IVB
C. Arrival Terminal				IVC

where delays actually occur are listed in the left margin. Each box is assigned a Roman Numeral-Letter designation and represents a different delay classification. The principal diagonal of the matrix--enclosed in the solid line--represents delays which occur in the same airspace segment as does their cause. Those boxes which are above the diagonal represent delays which take place, i.e., are experienced, in segments before the one in which the delay is caused. The shaded area which lies below the principal diagonal does not require classification.

Delay caused in a particular airspace segment cannot actually take place in airspace segments which the aircraft encounters after the segment of delay origin. (As an analogy, water backs up behind a dam, not in front of it.) An exception might be when departure delays cause arrival delays because there are too many aircraft on the airport surface to permit

additional aircraft to be landed. Although these types of exceptions do occur, they are for the most part atypical. The following paragraphs describe each type of delay and where it occurs.

Departure--Terminal: This delay (IA) is caused by events at the departure terminal and occurs exclusively at this terminal. The most frequent cause is weather. This type of delay is taken almost exclusively on the ground, consisting of wasted passenger and crew time but not aircraft operating costs.

Enroute (CONUS): Enroute delay occurs whenever an aircraft must take longer to complete a trip between two terminal areas than the minimum achievable time. Such delay occurs because the optimum route is not available for the aircraft for one of a number of reasons: (1) traffic volume between the two terminal areas may exceed that which may be accommodated by the optimum route, (2) severe weather may result in the optimum route being closed, (3) heavy traffic volume across the optimum route may require that an alternate route be flown. Delays generated by enroute events most likely will occur in the enroute airspace (IIB) and will consist of wasted passenger time, crew time and aircraft operating cost. It is possible under extreme conditions that such delays may back up into the terminal area (IIA). If they do back up into the departure terminal, they will most likely be taken on the ground.

Enroute (Oceanic): Enroute oceanic delay, like enroute CONUS delay, occurs when an aircraft takes longer to complete a trip than the minimum achievable. It is caused by the same factors as domestic delay. In the North Atlantic, limited optimum or near optimum air routes relative to demand for service are likely to be the primary cause. These delays may be experienced enroute (IIIB) or be pushed back to the departure terminal area (IIIA) where they usually will be taken on the ground.

Arrival Terminal: Delays generated in the arrival terminal airspace occur because the terminal cannot land aircraft at the rate they are arriving. This delay may actually occur in the terminal area (IVC) but most often backs up into enroute airspace (IVB) so as to avoid congestion in the terminal area and permit aircraft to hold at higher altitudes where they are more fuel efficient. (Note that most holding stacks are in enroute airspace.) At times, these delays may back up all the way to the departure terminal where aircraft bound for congested terminals will be held on the ground (IVA).

C. Cost Savings

Investment and regulatory decisions may result in cost savings to both the private sector, the FAA, and other governmental agencies. These savings may come in the form of direct cost savings where actual dollar outlays are reduced, or they may be reflected in efficiency gains. In the second case, output levels achievable with existing resources go up,

but actual costs remain constant. Given enough time, it is usually possible to shift such resources from one use to another if it is not desired to increase output by the full amount made possible by the increased efficiency.

Examples of direct cost savings are investments and/or regulations which reduce utility costs or fuel consumption. Included would be investments in more efficient heating and cooling equipment, aircraft engines, and solid state electronics. Also under this category would be regulations or procedures to minimize fuel consumption such as fuel advisory delays (FAD) or profile descents. Direct cost savings of an investment or regulation should be measured as the actual value of the savings expected to occur.

An example of efficiency gains is agency investments to increase employee productivity. Included would be the automation of the air traffic control system which relieved controllers of many record keeping functions and the acquisition of word processing equipment. In the case of ATC automation, additional productivity has been reflected in greater output. For word processing equipment, it has been possible to shift employee resources away from document preparation to other tasks. These gains should be measured by the value of the additional benefits which the more productive workers can now provide. For ATC automation this

would be the value of the additional output. For word processing equipment, it would be the value of the other tasks which employees may now perform.

D. Other

The above categories constitute most of the benefits that can typically be expected to flow from FAA investment and regulatory activities. Any analysis, of course, should include all known benefits whether or not they can be classified in the three major categories. As examples, the following presents other such benefits that have been identified in previous studies.

1. Noise Reduction

The provision of air transportation services generates noise which imposes costs or disbenefits on those who are subjected to this noise. Governmental activities have been undertaken to reduce aircraft-generated noise. The benefits of such activities are the reductions in noise-produced costs which these activities achieve. These benefits are equal to the maximum amount all impacted parties are willing to pay to avoid the noise. This amount may be approximated by half of the total aggregate decline in property values which results from the noise. 10/

10/ For a discussion of this method of measurement, including factors which determine the accuracy of the approximation, see E. J. Mishan, Cost-Benefit Analysis, Praeger Publishers, New York, 1976, pp 321-327.

The first step to measure the benefits of noise reduction is to identify the area around an airport which is impacted by noise. This area, designated as the noise footprint, may be determined by use of a model. One such model is the Federal Aviation Administration Integrated Noise Model. 11/ It permits the noise of different aircraft types on specified flight paths to be measured by one of several common noise measures. It is thus possible to measure the noise which currently exists and that which will exist after a change in aircraft type mix, flight path, or other variables.

The measures of noise provided by the model deal with two characteristics of noise: noise intensity and the cumulative number of occurrences of the noise events. Noise intensity measures are useful for such purposes as measuring the noise generated by a particular engine or in determining the amount of soundproofing required to achieve desired indoor noise levels. The general annoyance associated with noise is usually best assessed by a cumulative measure. One such measure is the Noise Exposure Forecast (NEF). Scaled in decibels, it represents the cumulative impact of aircraft noise over a 24-hour period, weighted for the time of day.

The second step is to determine the change in aggregate property values in the area impacted by noise. Several studies have been undertaken which measure the impact of noise or its absence on the value of property. 12/ Their results indicate that a one unit decrease in NEF

11/ FAA Integrated Noise Model Version I: Basic User's Guide, Report No. FAA-AEQ-78-01, Department of Transportation, January 1978.

12/ See Aircraft Noise References at chapter end.

can be expected to result in between a .2 and a 2.6 percent change in property values. One of the most recent of these studies, which avoids many of the technical deficiencies of the earlier ones, is William Fromme, Conceptual Framework for Trade-Off Analysis of Multiple Airport Operation: Case Study of the Metropolitan Washington Airports, University of Maryland, Ph.D. Thesis, 1978. Fromme's estimate of 1.5 percent is near the midpoint of the range of the others. It is suggested that this value be used unless there are compelling reasons to use another. The actual computation procedure involves ascertaining the value of the property in the area where noise reduction occurs. The change in aggregate property values is then equal to 1.5 percent of this value for each NEF of noise reduction achieved.

The final step requires that the change in aggregate property values be translated into a measurement of how much the affected parties would be willing to pay to avoid the noise. This amount may be approximated as half of the noise-produced decline in aggregate property values.

2. Missed Approach Benefit

In making an instrument or visual approach to a landing, the pilot almost always has the option of aborting the approach if it is judged to be unsatisfactory, by executing what is known as a missed approach. This requires the pilot to fly around and try again. This maneuver, called a

go-around, results in both aircraft operating expenses and wasted time. The missed approach benefit arises when certain approach aids which help reduce missed approaches and avoid go-around costs are installed.

This benefit is incorporated directly in the "Approach Aid Establishment Criteria Model." The model calculates the probability of a missed approach being averted by a landing aid. It then multiplies this probability by the cost of a go-around to obtain the missed approach benefit per operation. Specific methodology, which may be applicable to other analyses, is contained in "Missed Approach Probability Computations of the FAA/SCI (vt) Approach Aid Model," Interim Draft Report, Contract DOT-FA78WA-4173, October 1980.

3. Avoided Accident Investigation Costs

Another cost of aviation accidents, in addition to fatalities, injuries, and property damage, is the cost of investigating them. The National Transportation Safety Board (NTSB) is responsible for the investigation of all aircraft accidents; accidents involving air carriers or the loss of human life are usually investigated directly by NTSB. NTSB conducts two types of investigations: major accident investigations and regular accident investigations. Major investigations are conducted primarily for major air carrier disasters involving numerous fatalities and substantial property damage. They are characterized by the dispatch of

an investigative party--go team--to the accident site and usually involve substantial support by the FAA and involved private parties such as the airline, airframe and engine manufacturers, etc.

Regular investigations are much smaller in scope than major investigations. They are conducted for air carrier accidents involving limited loss of human life and for most fatal general aviation accidents. Responsibility for most other accidents--predominantly non-fatal general aviation accidents--is usually delegated by NTSB to FAA. FAA investigations are usually somewhat smaller in scope than NTSB regular investigations. About 30 percent are conducted by telephone and involve no fieldwork.

Costs for each type of investigation and average investigation costs for air carrier and air taxi or general aviation are reported in Table 3-1. Since some air carrier accidents are followed by NTSB major investigations and others by NTSB regular investigations, average air carrier investigation cost is a weighted average of NTSB major and regular accident investigation costs. The weights are the typical number of major and regular NTSB air carrier investigations conducted annually.

Similarly, the air taxi or general aviation average is a weighted average of NTSB regular investigations and FAA investigations. The weights are the typical number of such investigations conducted by each agency.

For purposes of benefit-cost analysis, it may be appropriate to use one set of cost figures for certain purposes and another for other purposes. For example, in evaluating approach and landing aids, the large chance that a preventable accident will result in many fatalities suggests that it will be followed by an NTSB major investigation if air carrier, or an NTSB regular investigation if general aviation. NTSB major and regular cost data should be used here. In evaluating a tower establishment, on the other hand, where a significant number of preventable accidents are not fatal, NTSB regular or FAA investigations are likely to follow any accident. Average cost figures are probably more appropriate in this type of situation.

TABLE 3-1

ACCIDENT INVESTIGATION COSTS [a]
(1980 dollars)

Type of Investigation	Cost
NTSB Investigations	
Major	$614,551
Regular	7,601
FAA Investigations	941
Weighted Average By User Type	
Air Carrier	214,516
Air Taxi or General Aviation	2,307

a/ Based on Stefan Hoffer, "Aviation Accident Investigation Costs," Office of Aviation System Plans, November 29, 1978.

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CHAPTER 4

COST ESTIMATION

I. General

Cost is defined as the resources that will be consumed if an objective is undertaken. The value of consumed resources is measured by the yardstick of dollars. This makes different cost elements comparable with themselves as well as with benefits. In addition, because resource value indicates what resources are required for a particular proposed objective, it is a measure of the cost of other objectives that cannot be pursued. Each alternative method of accomplishing the objective will have its own associated cost. Costs include all capital, labor, and natural resources required to undertake each alternative whether they are borne by FAA, other governmental units, various components of the total flying public, the general public, or some other particular group. Inclusion of costs borne by all groups is required in order to measure the total value of what must be forgone to undertake each alternative and to avoid errors in answering the economic questions.

An example of the need to consider total cost is that associated with the adoption of a new avionics system such as the micro wave landing system. Wheth r or not the system is worth undertaking depends on whether total benefits exceed or equal total costs. Total costs consist of all governmental costs to provide the system and private costs to users to purchase the new avionics. Undertaking the project where benefits exceed only the private or the governmental costs but not total costs would be improper. It would result in the value of resources consumed exceeding the benefits of the system for an overall net loss of value.

II. Concepts

A. Opportunity Cost

This is the value of the benefits foregone when resources are shifted from satisfying one objective to satisfying another. An all inclusive "measure", it represents what society as a whole--government and all private groups--must give up to obtain the desired objective. It is the theoretically correct measure of cost for use in economic analyses of governmental projects. As an example, the opportunity cost of the Nation's air transportation system is what the resources used to construct it--aluminum, concrete, electronic components, instructor time, etc--could produce in their next best use.

B. Sunk Costs

These are costs which have already been incurred. The resources represented by these costs have already been consumed and cannot be recovered. As a consequence, they are not relevant for current decisionmaking simply because nothing can be done about them. For example, the decision to add a glide slope to a localizer should be based strictly on the additional benefits and costs associated with the glide slope. The costs of installing the existing localizer and the benefits derived therefrom are irrelevant because they have already been incurred.

C. Average Incremental Cost

This concept is an attempt to implement the economist's concept of marginal cost--the increase in total cost associated with a small increase in the production of any particular service or product. Small increases are defined with respect to the infinitesimal changes of the differential calculus or unit changes of the discrete calculus. In the real world, feasible changes in the size of a project are usually much larger. Average incremental cost is defined as the change in total cost divided by the change in total output over a range that is feasible to achieve.

As an example, the ultimate constraint on airport capacity is the number of runways. When existing runways are operating as efficiently as possible, additional capacity can be obtained only by adding a new runway. An increase of one runway is the feasible change in service level in this case, and average incremental cost is the cost of this runway divided by the total operations that it can handle.

D. Out-of-Pocket Costs

These are actual cash outlays. Frequently, they represent only a part of the total cost of a project. Other costs can arise if resources required by a project are already owned by the government. When they are consumed by this project there is an opportunity cost in that they cannot be used in another use, but there is no cash outlay. Care must be taken in the exercise of economic analysis that all costs, and not just out-of-pocket costs are included.

E. Depreciation

Frequently, large costs must be incurred in the beginning of a project in order to obtain benefits (or revenues) in later years. It is often useful to know by how much annual benefits (or revenues) exceed annual costs, or the net benefit (or income) of the project. In order for this

value to be reasonable, it is necessary to allocate the large initial costs to later years when benefits occur. This is done by the accounting methodology of depreciation. While depreciation is important in determining reasonable annual accounting net benefits or income, its use in economic analysis is limited.

Economic analysis is concerned with when resources are consumed and when their benefits occur. Depreciation does not provide such information. Depreciation methodology, however, may have applications in estimating salvage values. To yield reasonable results, such depreciation must relate the asset's age to its actual value. Essentially arbitrary depreciation schemes designed for tax or other purposes must not be used for calculating salvage values.

F. Inflation

The cost of resources consumed and benefits provided are measured by the yardstick of the dollar. This yardstick itself often changes from year to year. The process of a decreasing (increasing) value of the dollar is known as inflation (deflation). For cost or benefit estimates to be comparable from period to period requires that a constant yardstick of value be used. This may be achieved by measuring everything in the dollars of any particular year.

Such estimates are said to be in the constant dollars of a particular year. Estimates where the benefits or costs of any particular year are measured in the dollars of that particular year are said to be current dollar estimates. The process of converting current dollar values to constant dollar values is explained in detail in Chapter 7.

III. Life Cycle Cost Model

The fundamental cost problem is to determine the total economic costs of proposed alternative future investments and regulatory actions. The life cycle cost model accomplishes this objective. It systematically identifies the total cost to the government and public of establishing and operating or complying with an investment project or regulation. It also specifies when during an activity's life specific costs are incurred; such information is required as input to the decision criteria described in Chapter 5.

This section develops a generalized scheme by which to classify the costs of proposed investment projects and regulations. Costs are organized under four general headings: Research and Development Cost, Investment Cost, Operations and Maintenance Cost, and Termination Cost. Under each heading numerous specific costs are indicated. The classification is deliberately detailed, being intended to cover many potential situations. It is not expected that all items identified below will be

relevant to the evaluation of any particular proposed project or regulation. Also, it is very likely that costs specific to particular projects may be omitted below.

A. Research and Development Costs (R&D)

This category sh uld include all costs incurred prior to procuring the system under evaluation or issuing a final regulation, except those costs that have already been incurred at the time the analysis is undertaken. Incurred costs are sunk costs and are not relevant for decisionmaking purposes. Specific types of typical R&D costs are:

- Feasibility Analysis
- Prototype Hardware
- Test Facilities
- Technical Experiments
- Operational Tests
- System Design and Engineering
- R&D Oriented Software
- Modeling and Simulation
- Regulatory Analysis (prior to issuance of a final regulation)

B. Investment Cost (including Facilities and Equipment)

These costs are initial outlays associated with getting the investment or regulation implemented and occur early on in an activity's lifetime. They typically consist of one or more of the following: land, facilities and equipment, and regulatory implementation costs.

1. Land

Included here are all interests in land that are acquired for the project: purchases, leaseholds, easements, air rights, mineral rights, etc.

2. Facilities and Equipment (F&E)

Facilities consist primarily of buildings and other real property improvements. They may encompass new construction, modifications to existing facilities, and leasehold interests. Equipment consists of items required to accomplish an activity other than facilities. Examples of FAA equipment are the non-facility components of ARTS, VOR, and the agency's aircraft. For private parties, examples are avionics, aircraft equipment, and aircraft instrumentation. Other items such as furniture or tools would also be classified as equipment.

Guidance in preparing F&E cost estimates for many established FAA projects is contained in F&E Cost Estimating Procedures and Summaries Handbook, FAA Order 6011.4, September 23, 1976. This order sets out a framework for estimating the F&E cost of almost any FAA project. It contains cost estimates for many established F&E programs. Estimating techniques for several common cost components such as freight and factory inspections are also provided. Although the order pertains only to FAA F&E costs, the framework it develops may be useful in preparing cost estimates for F&E type costs which investment projects or regulations require the public to undertake.

FAA form 2500-40, reproduced here as Figure 4-1, contains the format prescribed by the order for making F&E cost estimates. Although the distinction between Washington office cost and regional cost is largely arbitrary, it will be retained here because much existing data are classified this way. In Figure 4-1, regional costs are divided into five categories: plant engineering, electronic engineering, construction costs, electronics installation, and flight inspection. Each of these categories consists of one or more cost elements: various types of labor services, flight inspection services, other construction or installation costs, and land.

All labor categories must be estimated for any particular project. These should be adjusted for benefits and leave usage as explained below under O&M personnel costs. Flight check costs should be based on use of light twin turbojets unless larger aircraft will be required. The analyst is cautioned that these estimates may need to be adjusted to current year dollars in that the order is not updated each year. (Techniques to make such adjustments are in Chapter 7). Moreover, the dollar estimates in FAA Order 6011.4 are stated in current dollars of the fiscal year which is two years later than the date of publication of the most recent revision. This occurs because the estimates are prepared for budget purposes, and budgets are developed two years in advance of anticipated expenditure.

<u>FIGURE 4-1</u>

FAA FORM 2500-40

RIS: [illegible]

F & E COST ESTIMATE SUMMARY (FY-)

PROGRAM IDENTIFICATION						PROGRAM SUB-MISSION		LINE NO.	ACTION	PROJECT		LOCATION			RUNWAY	
BUDGET ITEM	PROJECT CODE				ORIGINATOR	FY	S			SUBMIT ORGANIZATION	REGION	ID		[illegible]	NUMBER	LETTER
	FACILITY		WORK CODE	SUP-FIX												
(1-2)	(3-6)	(7)	(8-10)	(11)	(12-13)	(14-15)	[illegible]	[illegible]	[illegible]	(19-20)	(21-22)	(23-25)	(26-27)	[illegible]	[illegible]	(31-32)

REGIONAL COSTS

	ITEM A		CARD COL. NO. B	DETAIL AMOUNT C	SUMMARY AMOUNT D	TOTALS E
				LAST POSITION - TENTHS OF THOUSANDS		
CARD 1	1. PLANT ENGINEERING	A. PLANT ENGINEERING (man-days + other costs)	(33-36)			
		B. DRAFTING (man-days + other costs)	(37-40)			
		☐ NONE REQUIRED — C. TOTAL				
	2. ELECTRONIC ENGIN.	A. ELECTRONIC ENGINEERING (man-days + other costs)	(41-44)			
		B. DRAFTING (man-days + other costs)	(45-48)			
		☐ NONE REQUIRED — C. TOTAL				
	3. CONSTRUCTION	A. LABOR (+ man-days)	(49-52)			
		B. OTHER CONSTRUCTION COSTS (Except land acquisition)	(53-56)			
		C. LAND ACQUISITION	(57-60)			
		☐ NONE REQUIRED — D. TOTAL				
	4. ELECTRONIC INSTAL.	A. LABOR (man-days)	(61-64)			
		B. OTHER INSTALLATION COSTS	(65-68)			
		☐ NONE REQUIRED — C. TOTAL				
	5. FLIGHT INSPECTION (hours at $ per hour)		(69-72)			
	6. REGIONAL UNIT COST					
	FOR WASHINGTON OFFICE USE ONLY	7. REGIONAL COSTS REVISED ☐ (If "Yes", enter "C" in box) (73)	8. MASS CHANGE INDICATOR ☐ (If "Yes", enter "M" in box) (74)			

CARD 2

9. SUMMARY OF MANPOWER REQUIREMENTS BY CATEGORY (Man-Days)

LINE NO. (17) 7 / ACTION (18)	PLANT ENG(1)	ELEC ENG (2)	CONSTR (3)	ELEC INSTL. (4)	FLT INSP (5)	COST CTR	MASS CHG.
	(33-36)	(37-40)	(41-44)	(45-48)	(49-51)	(52-55)	(74)

CARD 3

LINE NO. (17) 8

ACTION (18)

WASHINGTON OFFICE COSTS

	ITEM		CARD COL. NO.	DETAIL AMOUNT	SUMMARY AMOUNT	TOTALS
10. CONSTRUCTION MATERIAL	A. EQUIPMENT LIST ATTACHED		(33-37)			
	B. PROVISIONING (Parts common)	%	(38-41)			
	C. PROVISIONING (Other than parts common)	%	(42-45)			
	D. FACTORY INSPECTION	%	(46-49)			
	E. FREIGHT	%	(50-53)			
	☐ NONE REQUIRED — F. TOTAL					
11. ELECTRONIC EQUIPMENT	A. EQUIPMENT LIST ATTACHED		(54-58)			
	B. PROVISIONING (Parts common)	%	(59-62)			
	C. PROVISIONING (Other than parts common)	%	(63-66)			
	D. FACTORY INSPECTION	%	(67-70)			
	E. FREIGHT	%	(71-74)			
	☐ NONE REQUIRED — F. TOTAL					
12. F & E TRAINING		%	(75-79)			
13. WASHINGTON OFFICE UNIT COST						
14. TOTAL UNIT (Region + Washington Office) COST	TEMPORARY COSTS ☐ (If "Yes", enter "T" in box) (80)					

REMARKS	DATE

PROJECT TITLE / LOCATION	BUDGET ITEM	PAGE NO.

FAA Form 2500-40 PG 1 (9-71) SUPERSEDES PREVIOUS EDITION

Other construction costs consist of regionally funded items such as site preparation, building materials, utilities consumed by construction, cable installations, etc. Land includes all interests that are acquired for the project: purchases, leaseholds, easements, air rights, mineral rights, etc. Note that Order 6011.4 considers land as part of F&E cost rather than a separate investment cost component, as indicated by this handbook. This reflects the relatively small magnitude of most FAA land costs relative to total investment costs and is appropriate for projects where land costs are relatively small. For projects with relatively large land costs, it is recommended that a separate category be identified so has to clearly point them out.

Washington office costs represent construction material, electronic equipment, and initial F&E training. Note that the same cautions apply as for regional cost. FAA Order 6011.4 contains cost estimates for many projects. The order also presents methodology for estimating certain smaller F&E cost components where actual data are not available:

a. Provisioning Cost

Provisioning Costs are incurred for initial spare parts, special tools, special test equipment, and technical documents. When actual data are unavailable, the following information may be used to develop estimates in relevant situations.

TABLE 4-1

PROVISIONING COST ESTIMATING FACTORS

Equipment	Percent of Equipment Cost: Excluding Parts Common	Percent of Equipment Cost: Parts Common
RF Communication Equipment	26	4
Other Communication Equipment	16	4
ILS/VOR/TCACN/DME	11	4
RADAR/BEACON/RML	26	4
RADAR Displays	24	6
E/G, Lighting System, Weather Sensors, and related equipment	5	5

Source: F&E cost Estimating Procedures and Summaries Handbook, FAA Order 6011.4, September 23, 1976, p.4.

b. Factory Inspection

Factory inspection costs are incurred when FAA procures special order equipment, and FAA inspectors are sent to the factory to ensure that it meets government specifications. In the absence of actual cost data, these costs can be estimated as 3 percent of the cost of the material being procured.

c. Freight

Freight represents the transportation costs to get materials and equipment to the project sites. When actual data are not available, this item may be estimated as 10 percent of the cost of construction materials and 3 percent of the cost of electronic equipment.

d. Initial Training (including F&E training)

This category consists of initial costs incurred to train employees in the installation, known as F&E training, and maintenance of new equipment. Note that while Form 2500-40 includes only F&E training, initial maintenance training should be included as part of F&E investment cost for purposes of benefit-cost analysis. Initial training costs include travel, subsistence, and lodging associated with training, instructional costs, and compensation of employees being trained.

e. Initial Travel

These are the travel costs associated with getting the activity up and going. Although not indicated by a separate line on Form 2500-40, lodging and subsistence costs associated with F&E investments have been included in the regional labor cost estimates of FAA Order 6011.4. It is recommended that these travel costs, together with direct travel costs such as airfares, be considered in a separate category.

3. Regulatory Implementation Costs

The promulgation of a regulation will often impose investment costs on either the government, the public, or both. All of these costs must be considered in the evaluation of a regulation. Although investment costs imposed by regulations can potentially include any type of cost, most regulatory investment costs will consist of labor and equipment costs. At the very least, a new regulation will require an investment of employee time for affected parties to familiarize themselves with the regulation and establish a system for complying with it. In other cases, substantial investment will be required in training or equipment. For example, the establishment of a Type I Terminal Control Area requires that all aircraft operating within it equip with encoding altimeters and mode C transponders. And a requirement that all commercial pilots be instrument rated will require an investment in instrument training for those commercial pilots not instrument rated when the requirement is established and all new commercial pilots.

Equipment costs may be estimated using the methodology suggested for Facilities and Equipment cost, above. Familiarization, establishment of compliance procedures, and training will involve primarily employee labor costs, although some travel, training and record keeping or computer programming costs may be involved. Labor costs should be calculated as defined under Personnel Costs on page 4-15, below. Other cost elements must be estimated on a case by case basis. In most cases, the use of rules of thumb in estimating other cost elements is precluded by the heterogeneity of regulations.

C. Operations and Maintenance Costs (O&M)

These are the recurring costs required to operate and maintain the proposed investment project or to comply with the proposed regulation. These costs may occur annually or periodically every so many years.

1. Personnel Costs

These are a major component of recurring costs. They must be incurred to both operate and maintain any investment as well as comply with many regulations.

The first step in computing personnel costs is to determine the annual labor hours required by type of skill. These hours should include not only direct labor but such other items as recurring training, travel time, break time etc. Estimates for new systems or regulations can be developed based on engineering data or previous experience with similar types of undertakings. For existing ones, estimates can be based on actual experience.

A potential data source for many existing FAA systems is the FAA's staffing standards. 1/ The staffing standards are detailed models relating required staffing to the volume of work required to be done.

1/ Air Traffic Staffing Standards System, FAA Order 1380.33B, March 10, 1980; Airways Facilities Sector Level Staffing Standard System, FAA Order 1380.40A, August 1980; and Staffing Standards--Flight Standards Field Regulatory Programs, FAA Order 1380.28A, November 1975.

Each contains information on the staff required to provide specific services or maintain specific equipment. While potentially very useful, the analyst is cautioned to carefully screen staffing standard data for suitability for the analysis at hand. At times, it may contain assumptions or procedures which are inappropriate for benefit-cost analysis.

The second step is to adjust the required labor hours for annual leave, sick leave, and other absences. For many existing FAA systems, this may be accomplished based on estimates for these factors contained in the Staffing Standards. In other situations involving federal employees, required labor may be adjusted upwards by 18 percent, based on Office of Personnel Management data. [2/] For private sector employees, a 9.2 percent upward adjustment should be made. [3/]

The third step is to compute the effective compensation rate for each labor category. This requires that the stated compensation rates for each skill category be determined. Government employees are paid with respect to either the Wage Board (WB) or General Schedule (GS) pay scales. Stated compensation for Wage Board employees is expressed directly in hourly rates. General Schedule compensation is expressed in

2/ Cost Comparison Handbook, Supplement No. 1 to OMB Circular No. A-76, March 1979, p. 21.

3/ Statistical Abstract of the United States: 1980, Table 710.

annual salaries. These must be divided by 2080—the number of hours in a work year—to obtain hourly rates. Private sector employee stated compensation rates can be determined based on WB or GS compensation rates for equivalent skills or other data which may be available on a case by case basis. For project or regulation evaluation purposes, compensation levels associated with GS step 5 and WB step 3 should be used. If the project or regulation involves labor requirements at times other than the regular work day, such additional items as night differential or weekend pay should be added to the basic compensation rates to the extent they are expected to occur. Post differentials, such as those paid to employees serving in Alaska, should also be included.

Effective compensation rates are obtained by adjusting stated compensation rates to reflect the value of various fringe benefits—allowances and services provided to employees as compensation in addition to the wages or salaries used in determining the stated hourly or annual rate of pay. These may be grouped into three categories: retirement and disability, health and life insurance, and other benefits. Current acceleration factors for each are indicated in Table 4-2 for permanent employees under civil service retirement and for private sector employees. The factors given for private sector employees are an average for the overall private sector. Because benefits vary widely in the private sector, more specific data should be used when estimating effective compensation levels for specific private sector employees when such data is available.

The reader should note that the absence and benefit factors given for permanent Government employees are not comparable with those given for the private sector. The Government workforce does not mirror the private workforce but tends to consist of higher than average skill level employees. In the private sector, such employees tend to receive higher than average benefits and paid absences.

TABLE 4-2

FRINGE BENEFIT FACTORS

Category	Percent	
	Permanent Government	Private Sector
Retirement and Disability	20.4%	13.6
Health and Life Insurance	3.7%	5.4
Other Benefits	1.9%	4.0
Total	26.0%	23.0

Source: Cost Comparison Handbook, Supplement No. 1 to OMB Circular No. A-76, March 1979, p. 24, and Statistical Abstract of the United States: 1980, Table 710, as adjusted for Social Security tax changes.

For federal employees who are not under the Civil Service Retirement System (normally temporary employees), stated compensation rates should be adjusted to reflect the government's share (as employer) of Social Security taxes (FICA). These rates change from time-to-time and are applicable for each employee only up to a maximum salary. Where such estimates must be made, care should be exercised that current tax rates are used and that the rates are applied only to wages below the maximum applicable salary.

The fourth and final step is to translate annual labor requirements for each required skill into dollars. This is accomplished by multiplying the annual labor hours required (from step 2) by the appropriate effective hourly compensation rate (as determined in step 3).

2. Materials

Materials are made up of such items as repair parts, small tools, lubricants, and other items which are consumed annually by the operation and maintenance of a system. For FAA systems, O&M materials costs are classified under two headings: "spare and repair parts" and "other objects." Spare and repair parts are supplied through the depot in Oklahoma City. Costs associated with a particular project may be obtained from ALG-240. Other objects are provided by the FAA regional organization and include all other required material costs. Costs specific to a particular project may be obtained from AAF-150.

3. Utilities

Included here are the costs of electricity, gasoline, natural gas, water, etc. Estimates of these expenses for the initial year of implementation should be based on current experience for existing systems and engineering estimates for new systems. Future estimates should be made by adjusting initial year estimates for anticipated future experience.

4. Recurring Travel and Transportation

This item represents the direct costs of travel and transportation necessary to undertake a project. It consists of such items as airfares, subsistence payments, lodging, and depreciation and operating costs of government vehicles. It does not include wages or salaries paid to employees while in travel status; these are defined to be included in personnel costs above.

5. Recurring Training

This category represents training costs to maintain employees' skills and to train new employees. It includes training, specific travel costs, and, for FAA undertakings, Academy costs. It may be defined either to include or omit compensation to employees being trained. It is important, however, that such compensation be included either here or under personnel cost and that double counting be avoided.

D. Termination Costs

1. Dismantling Costs

These are the costs, if any, required to disassemble and remove old equipment at the end of its lifetime.

2. Site Restoration

This is the cost, if any, to restore the site on which the old equipment was located to its original or near original condition. It may involve grading of earth, reforestation, or landscaping.

E. Salvage Value

Salvage value is the value, if any, of the project equipment to the government at the end of the expected project life. Note that it is treated here as an offset to termination costs.

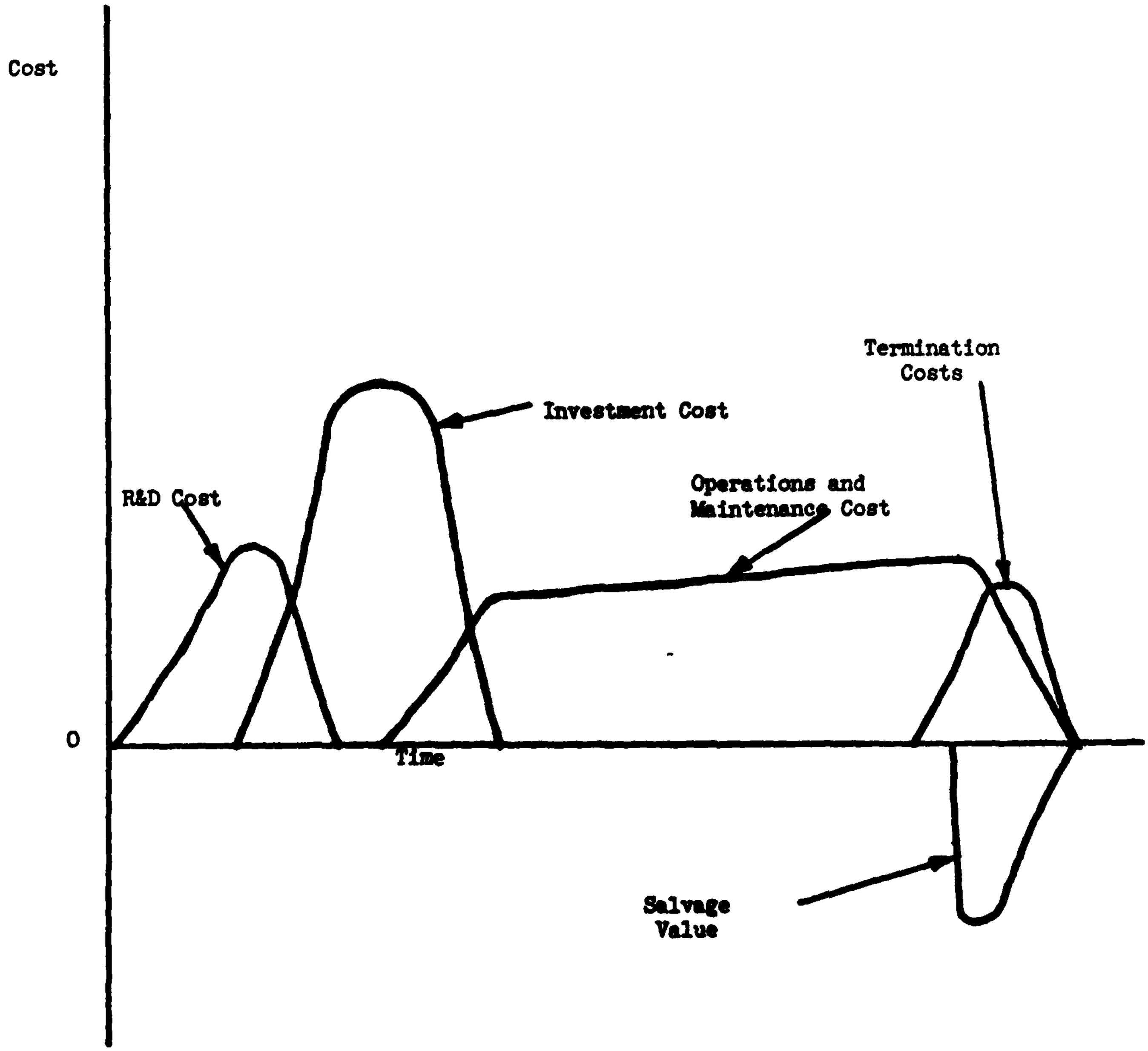
F. Relationship of Cost Components

Figure 4-2 presents an "idealized" summary of major life cycle cost components over an activity's life. While not all activities will follow this pattern; more will resemble this pattern than any other pattern. As indicated, research and development costs increase every year from project inception up until the beginning of the investment phase, after which they rapidly diminish. Investment costs need follow no particular pattern except that they occur over a relatively short period. Operating and maintenance costs rise rapidly following initial investment as facilities and equipment of the project are brought on-line or a

regulation is fully implemented. After the investment phase is completed, operating and maintenance costs will continue to rise slowly as a result of increasing equipment age. Near the end of the project life, operating and maintenance costs decline as equipment is retired. Retirement also gives rise to termination costs and salvage value.

FIGURE 4-2

LIFE CYCLE COST SUMMARY



CHAPTER 5

MULTI-PERIOD ECONOMIC DECISION CRITERIA

I. Requirement to Discount

This chapter presents methodology with which to make the comparison of investment or regulatory alternatives required by step 6 of the economic analysis process. The methodology accounts for the characteristic that benefits and costs occur over a number of years. It explicitly recognizes that otherwise equal benefits or costs which occur at different points in time will not be equal when viewed from a common point in time. Generally, a benefit will be worth more the sooner it is received, and a cost will be less the longer it is deferred. This economic phenomena is the result of two factors: the productivity of capital and the time preference of economic decision makers.

An observed fact of economic life is that production processes which employ capital--buildings, machines, organized methods such as assembly lines, etc.--are frequently more productive than other production methods. Such methods are not only able to recover the costs of the resources to build the capital, but return something in addition to this. This additional return, known as the net productivity of capital, provides an incentive to undertake every activity for which it exists. Unfortunately, there are insufficient resources to carry out all such projects.

At any particular time, the quantity of resources in an economic system is fixed. They may be divided between current consumption and capital investment, which implies future consumption. However, there is a general predisposition for people to prefer current consumption over future consumption, or to have a positive time preference. In very poor subsistence level economic systems, immediate consumption of everything, or almost everything, may be necessary for survival. But even in wealthier systems, either because of general impatience, or the ever present probability of death, or some other reason, people are willing to invest in the future only to a limited degree.

As a consequence, only some of the many activities capable of returning more than their cost can be undertaken. Rational decision making requires that those activities with greater returns over cost be undertaken before those with smaller returns until all investable resources are exhausted. The last activity undertaken before exhausting the investable resources should have a return less than or equal to all activities actually undertaken and greater than or equal to all activities not undertaken. This level of return, known as the marginal rate of return of capital, represents the prevailing level of capital productivity that can be achieved at any particular time by investing resources. Because any investment undertaken can earn at least this rate, it is the opportunity cost of making an investment. The marginal rate of return on capital is commonly expressed as an annual rate, and will be referred to here as the discount rate.

The need to discount arises because resources currently available can be invested and a larger amount obtained in a future period. Any future amount must be diminished to reflect the present amount required to be invested to yield the future amount. Before proceeding, it is emphasized that the requirement to discount does not depend upon the existence of inflation. Rather it arises from the productivity of capital and the scarcity of investable resources. Even in an inflationless world, discounting is required. The appropriate treatment for inflation in investment analysis will be discussed in Chapter 7.

II. Discounting Methodology

For a period of one year, an investment can be expected to grow at some rate, as shown by equation (5-1):

$$O_1 = I + rI = I\,(1 + r) \qquad (5\text{-}1)$$

where: I = the investment's initial value,

O_1 = the investment's value in one year, and

r = the growth rate.

For a period of two years, investment growth is given by:

$$O_2 = I\,(1 + r)(1 + r) = I\,(1 + r)^2 \qquad (5\text{-}2)$$

Here the growth rate is applied, in succession, twice because the investment is allowed to grow for two years. Similarly, for a period of n years the growth rate is applied n times:

$$O_n = I\,(1 + r)^n \tag{5-3}$$

The significance of equation (5-3) is that it indicates the extent to which resources invested today (I) can be transformed into outputs in the future (O_n) for any growth rate r. By dividing through by $(1 + r)^n$, the equation also indicates the amount of current resources (I) required to produce future outputs (O_n) in n years:

$$I = \frac{O_n}{(1+r)^n} \tag{5-4}$$

It is equation (5-4) that is relevant to discounting. Once a minimum acceptable r is established, the maximum acceptable resource value required to produce an expected output of O_n can be estimated. Or in other words, I is the present value of O_n after being discounted over n years at rate r. As will be explained below, if the actual resources required to produce O_n are less than or equal to I, the project is worth undertaking. If they are more, it is not worth doing.

Equation (5-4) can be extended to a situation where outputs are generated and resources consumed in more than one period. This requires that several equations--one for each year--of the form of (5-4) be added together, as in (5-5):

$$I^1 + I^2 + \ldots I^n = \frac{O_1}{(1+r)^1} + \frac{O_2}{(1+r)^2} + \ldots + \frac{O_n}{(1+r)^n} \quad (5\text{-}5)$$

where: I^i = the initial investment associated with outputs in year i.

By defining O_t as the difference between benefits (B_t) and costs (C_t) in year t and their discounted value as their net present value, equation (5-5) may be rewritten in its usual form:

$$NPV = \sum_{t=o}^{k} \frac{(B-C)_t}{(1+r)^t} = \sum_{t=o}^{k} \frac{B_t}{(1+r)^t} - \sum_{t=o}^{k} \frac{C_t}{(1+r)^t} \quad (5\text{-}6)$$

where: NPV = the discounted net present value of a series of outputs and resource inputs, and

k = the total number of periods in the evaluation period of the project or regulation.

III. Evaluation Procedure

A. Discount Rate

As noted above, the discount rate should represent the generally prevailing rate of return on capital in the private sector. For purposes of evaluating U.S. Government investment activities, the Office of Management and Budget has specified that this rate is approximately 10 percent. The OMB determination, contained in OMB Circular No. A-94 of March 27, 1972, is based on estimates of the rate of return to capital in the private sector of the U.S. economy before federal income taxes and net of inflation.

B. Net Present Value

To compute NPV, each element of the summation of (5-6) must be evaluated. The first step is to estimate the value of activity benefits each year for each alternative. Next, the costs for each alternative must be estimated and subtracted from the benefit estimates. (Procedures for estimating benefits and costs are developed in Chapters 3 and 4, respectively.) The resulting net benefit in each period t must then be discounted—divided by $(1 + r)^t$—and the resulting values added up to obtain the net present value of the alternative. Because the values of $(1 + r)^t$ are used repeatedly in analysis after analysis, they have been calculated and published in tables. Table 5-1 presents an example of such table calculations; detailed tables are contained in Appendix C.

TABLE 5-1

REPRESENTATIVE END OF PERIOD DISCOUNT FACTORS FOR 10 PERCENT DISCOUNT RATE

Years From Present	Factor
0	$1/(1+.1)^0 = 1.000$
1	$1/(1+.1)^1 = .909$
2	$1/(1+.1)^2 = .826$
3	$1/(1+.1)^3 = .751$
4	$1/(1+.1)^4 = .683$
5	$1/(1+.1)^5 = .621$

Up to now it has been implicitly assumed that all benefits or costs occur at the end of a period and are discounted for this period to reflect receipt at the period's end. Actually, several assumptions are commonly employed with respect to when benefits or costs occur within each period. The most conservative assumption--yielding the lowest NPV for given streams of benefits and costs--is to assume that all costs occur at the beginning of a period and all benefits at the end. This assumption involves discounting the stream of benefits by one more time period than the stream of costs. That is, costs incurred in the first time period are not discounted at all while benefits in this period are discounted by one period; in the second period, costs are discounted by one period and benefits by two periods, and so on. This assumption is commonly used with financial calculations where money is advanced at the beginning of a period and paid back at the end of the period with interest.

Another common assumption is to assume that all benefits and costs occur at the mid-point of a period. Such a procedure attempts to approximate the reality that benefits and costs occur throughout each period for most investment activities. The discounting procedure involves applying the discount factor for half a period in the first period, one and a half periods in the second period, and so on. Table 5-2 presents an example of such factors. In practice such factors need not be used. All that is necessary is to discount using end of year factors and then multiply the results by 1.048809. Multiplication by this factor, equal to $1/(1+.1)^{1/2}$, has the effect of moving all the end of year discounted values closer to the present by a half a year.

TABLE 5-2

REPRESENTATIVE MID-PERIOD DISCOUNT FACTORS FOR
10 PERCENT DISCOUNT RATE

Years From Present	Factor
0	$1/(1+.1)^0 = 1.0$
1	$1/(1+.1)^{1/2} = .953$
2	$1/(1+.1)^{1\ 1/2} = .867$
3	$1/(1+.1)^{2\ 1/2} = .788$
4	$1/(1+.1)^{3\ 1/2} = .716$
5	$1/(1+.1)^{4\ 1/2} = .651$

The final assumption commonly employed is that benefits and costs occur continuously over the period and are discounted continuously over the period. This procedure explicitly recognizes that benefits and recurring costs very likely occur throughout a period, rather than at its beginning or end. Moreover, one-time costs projected to occur in the more distant years of an activity's life, such as major overhauls or modifications, are unlikely to occur only on anniversary dates. The continuous procedure assumes an equal probability of the occurrence of such one-time costs throughout the year. Representative discount factors are presented in Table 5-4; complete tables are contained in Appendix C. The computation of these factors is beyond the scope of this handbook. The interested reader is referred to any standard engineering economics text. 1/

From a practical point of view, the mid-period and continuous procedures are about the same. Either can be used to approximate the continuous characteristic of benefit and cost streams. Also, there is not a large difference between the end of period discounting and either mid-period or continuous discounting--slightly less than 5 percent at a 10 percent discount rate. And assuming costs to occur at the beginning of the period and benefits at the end has the effect of increasing costs relative to benefits by ten percent. The relatively small changes produced by changing discounting procedures suggests that, with respect to project and regulation evaluation, any of the methods is acceptable.

1/ For example: E. Paul DeGarino and John R. Canda, Engineering Economy, Fifth Edition, MacMillan Company, New York, 1973, pp. 143-146.

TABLE 5-4

REPRESENTATIVE CONTINUOUS DISCOUNT FACTORS
FOR CONTINUOUS FLOWS AT 10 PERCENT DISCOUNT RATE

Years From Present	Factor
0	.954
1	.867
2	.788
3	.717
4	.652
5	.592

However, the mid-period or continuous procedures have conceptual appeal because they explicitly recognize the continuous nature of benefits and costs. It is recommended that one of these two methods be utilized.

C. Special Cases

The computation procedures for determining NPV can be simplified substantially in two special situations. The first is where the flow of benefits and costs each period are equal and occur for a finite number of periods. In such cases, the present value of the streams is given by:

$$NPV = \sum_{t=o}^{k} F_t \, (B-C) \qquad (5-7)$$

Where: F_t = the appropriate discount factor at a given interest rate for the period t periods from today, as discussed above in Section IIIB and given in Tables C-1 and C-2 of Appendix C.

Because (B-C) is constant across all periods, it may be removed from the summation to yield (5-8):

$$NPV = (B-C) \sum_{t=o}^{k} F_t \qquad (5-8)$$

Values for $\sum_{t=o}^{k} F_t$ for various discount rates and values of k are tabulated in Tables C-3 and C-4 in Appendix C. Given the evaluation period of an activity, k, and the discount rate, the analyst need only determine the appropriate value from the table and multiply it by the annual net benefit amount to determine NPV.

A second special case occurs when the flow of benefits and costs each period are equal and occur forever. Such a situation is known as a perpetuity. The present value of such a stream can be calculated very easily by dividing the flow per period by the discount rate, as indicated by equation (5-9). The computation is particularly convenient when using the OMB prescribed discount rate of 10 percent; it is only necessary to shift the decimal point of the per period flow to the right by one place. Also, note for convenience that (5-8) can be approximated by (5-9) when the discount rate is 10 percent and the number of periods greater than 30 with an error of about 5 percent or less.

$$NPV = (B-C)/r \qquad (5\text{-}9)$$

D. Evaluation Period

The number of years over which the benefits and costs of an investment or regulation should be considered may be designated as the evaluation period. This period may be defined with respect to either the length of time over which the good or service to be produced will be required or the economic life of the investment required to produce it. The choice of method is dependent on the circumstances of the analysis. Because either method will yield the same results, the choice can be made based on considerations of practicality.

Three time periods are of concern in determining the evaluation period: requirement life, physical life, and economic life. The requirement life is that period over which the benefits of the good or service to be provided or mandated by regulation will be greater than the costs of producing it. It can be for a very short period of time such as a requirement to provide special air traffic control services to an air show held at an otherwise uncontrolled airport. Or it may be for a very long period of time such as the provision of en route surveillance radar coverage. From a practical point of view, requirement lives in excess of 30 years can be regarded as infinite; the costs and benefits occurring in the periods beyond 30 years are discounted to the degree of being insignificant.

The physical life is that period for which facilities and equipment can be expected to last. It is to a considerable degree under the control of the decisionmaker. Not only can alternative facilities and equipment with different physical lives resulting from inherent quality differences be procured, but maintenance policies can be varied to alter an asset's physical life after it has been put in service.

The economic life is that period over which an asset can be expected to meet the requirements for which it was acquired at the lowest achievable cost. Thus, by definition, economic life is less than or equal to requirement life. Economic life may be equal to physical life but it is frequently less. If less, this indicates that it is not efficient to

operate the asset as long as possible. Rather, it is cheaper to replace it. The need to replace often occurs as the consequence of ever rising maintenance costs, particularly for relatively old items. Estimates of economic lives should be based on actual information where possible. In the absence of such information, the guidelines in Table 5-4 may be used. Note that these guidelines are deliberately short so as to minimize the periods over which benefits can be attributed to any given capital expenditure. Longer useful lives may be used where they can be justified.

Although the evaluation period may be defined with respect to either requirement life or economic life, investment projects or regulations requiring specified investments--design regulations--are usually evaluated over their economic lives. Use of the requirement life method would require the assumption that the facilities and equipment would be replaced at the end of each economic life period forever. Such assumption, while not improper, would add little to the analysis. Moreover, it might obscure the fact that equipment performance is likely to improve with time and that better performance, lower cost replacements are likely to be available in the future.

Analysis of regulations which mandate provision of a good service but which do not specify the method of production are known as performance regulations. They cannot be evaluated over the economic life of the required investments because the equipment has not been specified and its life is, thus, unknown. Performance regulations should be evaluated over

TABLE 5-4

USEFUL LIFE GUIDELINES

Item	Useful Life In Years
Aircraft	10
Equipment, Electrical	15
Equipment, Mechanical	10
Structures, Permanent	25
Structures, Temporary	20

Derived From: Department of the Navy, Facilities Engineering Command, Economic Analysis Handbook, July 1980, p. 14; Department of the Treasury, Internal Revenue Service, Revenue Procedure 77-10, 1977, and Department of Transportation, Capital Stock measures for Transportation, December 1974, Volume I, Chapter 5.

the requirement life. The length of time for which a regulation is required must be determined on a case by case basis. In those cases where it is anticipated that the mandated new good or service will become a permanent part of the NAS, the requirement life may be treated as infinite.

Regardless of the evaluation period selected, it should extend over the same number of years for each alternative. This is necessary because benefits and costs are flows and must be measured with respect to time. In certain situations, it will not be possible to compare alternatives with the same number of time periods. This situation frequently arises when an existing facility is being compared with replacements. The existing facility will continue to be functional for sometime; however, its physical life probably will not extend beyond the economic life of the new replacement alternatives. Techniques for dealing with this type of situation are presented in Section IV-C.

IV. Alternative Decision Criteria

A. Net Present Value

The net present value (NPV) criterion requires that equation (5-6) be evaluated for all investment or regulatory alternatives. The criterion provides that the alternative to be undertaken (1) have a positive NPV and (2) be that one which has the highest NPV of all alternatives. Condition (1) insures that the activity is worth undertaking; that is, it contributes more in benefits than it absorbs in costs. Condition (2) results in the optimum amount of benefits being produced at the lowest achievable cost. The NPV criterion, then, answers both of the economic questions--what to produce and how to produce it.

As an illustration of the application of NPV, consider the following example. Several nondirectional radio beacons (NDB's) provide instrument approaches to several airports. The users of those NDB's enjoy benefits equal to $200,000 per year. The costs of maintaining the NDB's equals $100,000 per year. It is expected that the NDB's can continue in service another 30 years with negligible increases in operating and maintenance costs.

Four alternatives are being considered as replacements for the NDB's. Alternative A is to replace the existing NDB's with instrument landing systems (ILS) costing $30 million to acquire and $1 million to maintain

annually. Alternative B also involves ILS replacements for the NDB's. It costs $25 million to acquire and $1.3 million to maintain annually, the difference owing to a different geographic configuration. Alternatives C and D are VHF Omnirange (VOR) installations. Costs are shown in the Table below.

TABLE 5-5

ALTERNATIVE NAVIGATION AIDS
(millions of constant dollars)

Alternative	Initial Costs	Annual O&M	Annual Benefits
Existing NDB's	-0-	0.1	0.2
A -- ILS_1	30.0	1.0	5.0
B -- ILS_2	25.0	1.3	4.5
C -- VOR_1	20.0	1.6	4.0
D -- VOR_2	15.0	2.0	3.0

The varying amounts of benefits for each alternative, including the existing NDB's, result from the fact that more users will be better served by the more sophisticated ILS system than the VOR system and more users better served by both the ILS and the VOR installations than by the existing NDB system.

Using the OMB prescribed 10 percent discount rate and assuming a lifetime of 30 years for all alternatives, we find the present value of costs, benefits, and their difference, the NPV. As can be seen from Table 5-6, alternative A is the best one because it results in the greatest surplus of benefits over costs of all the alternatives.

TABLE 5-6

PRESENT VALUE OF COSTS AND BENEFITS
(millions of constant dollars)

Alternative	Initial Costs	Annual Costs	Total Costs	Total Benefits	Benefits Minus Costs
Existing NDB's	-0-	0.94	0.94	1.89	.95
A -- ILS_1	30.00	9.43	39.43	47.14	7.71
B -- ILS_2	25.00	12.26	37.26	42.42	5.16
C -- VOR_1	20.00	15.08	35.08	37.71	2.63
D -- VOR_2	15.00	18.85	35.85	28.28	-5.57

B. Benefit-Cost Ratio

Another investment criterion is the benefit-cost ratio. It is defined as the present value of benefits divided by costs, and is given by equation (5-10) [2/]

$$B/C = \frac{\sum_{t=o}^{k} \frac{B_t}{(1+r)^t}}{\sum_{t=o}^{k} \frac{C_t}{(1+r)^t}} \qquad (5\text{-}10)$$

The ratio indicates the present value of the dollar benefits that will result per present value of dollars invested. A proposed activity with a ratio of at least one will return at least as much in benefits as it costs to undertake. This corresponds to having a positive or zero net present value and indicates that an activity is worth undertaking.

2/ Equation (5-10) is written using discrete, end of period discounting. It could also be stated in terms of any of the other discounting conventions discussed above in Section IIIB of this chapter.

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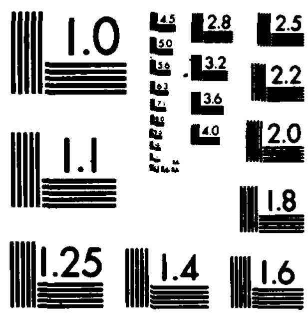


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

While the benefit-cost ratio criterion provides a correct answer to the first economic question of which objectives should be undertaken--defined as those with ratios greater than or equal to unity--it often fails to correctly answer the second question of how to accomplish the objectives most efficiently. The difficulty arises in chosing between competing alternatives to accomplish a particular objective which are mutually exclusive; that is, selection of one of them precludes selection of any of the others.

Again, consider the example of replacing a system of NDB's with VOR's or ILS's. Table 5-7 reproduces the NPV values from Table 5-6; it also presents benefit-cost ratios for the same altenatives. As can be seen, the results are quite different. As with the NPV criterion, every alternative other than D produces more in benefits than it costs. However, the benefit-cost ratio criterion indicates that the existing NDB system be retained because it yields the greatest excess of benefits over costs. The outcome is contrary to the NPV criterion which indicated that

TABLE 5-7

PRESENT VALUES OF BENEFITS AND COSTS
AND BENEFIT COST RATIOS

(millions of constant dollars)

Alternative	Benefits	Costs	Benefits Minus Costs	Benefits ÷ Costs
Existing NDB	1.89	.94	.95	2.01
A — ILS_1	47.14	39.43	7.71	1.20
B — ILS_2	42.42	37.26	5.16	1.14
C — VOR_1	37.73	35.08	2.63	1.08
D — VOR_2	28.28	33.85	-5.57	.84

the NDB's be replaced by the more expensive ILS system--alternative A. It is also wrong. If the alternative with the highest benefit-cost ratio is selected, it will provide an opportunity to earn the greatest return on the resources actually invested. But selecting it will preclude earning a positive, albeit smaller return, on additional resources that might be invested under one of the other alternatives. Only if all the alternatives have the same present value of costs will selecting the ratio with the highest value produce the economically correct result.

C. Uniform Annual Value

As an alternative to net present value, benefit or cost values may be expressed as annual uniform values (UAV). This involves dividing the present value of a stream of benefits or costs by the same factor that was multiplied by a constant valued stream in equation (5-8) to obtain a present value:

$$UAV = \frac{NPV}{\sum_{t=o}^{k} F_t} \qquad (5\text{-}11)$$

The factors denoted by $1/\sum_{t=o}^{k} F_t$ are known as capital recovery factors. They may be computed by taking the reciprocal of the values contained in Tables C-3 and C-4 of Appendix C.

The uniform annual method will produce answers to the economic questions which are identical to those produced by the NPV method. This follows by virtue of the fact that all the present values computed under the NPV

method need be only divided by the same constant to convert the results to a uniform annual basis. Table 5-8 presents the example of navigation aids expressed on a uniform annual cost basis. Also reported are ratios of annual uniform benefits and costs; note that the ratios are identical to those produced by taking the corresponding ratios of present values as reported in Table 5-6.

Historically, the UAV method was widely used for many years, particularly by civil engineers. Its widespread use probably had its origin in Wellington's classic work, The Economic Theory of Railway Location (1887). Wellington published during a time when most engineers worked for railways during at least part of their career, and he influenced the thinking of the entire engineering profession. Grant, whose first book on engineering economy was published in 1930, 3/ prefers to use the UAV method when making comparisons. However, in more recent years there has been a shift away from uniform annual values to net present value. This handbook recommends that NPV be used instead of uniform annual values. Not only does the NPV method focus attention on the total net benefits to flow from an activity, it also explicitly identifies the present value of all costs of an undertaking. Such explicit recognition of costs, discussed in Chapter 4, is known as lifecycle costing. It is required by OMB and Departmental directives (see Appendix A).

3/ Eugene L. Grant and W. Grant Ireson, Principles of Engineering Economy, The Ronald Press Company, New York 1964.

TABLE 5-8

UNIFORM ANNUAL VALUE OF BENEFITS AND COST
AND THEIR RATIOS

Alternative	Uniform Annual Benefits	Uniform Annual Costs	Uniform Annual Benefits Minus Costs	Uniform Annual Benefits ÷ Uniform Costs
Existing NDB	.20	.10	.10	2.01
A — ILS_1	5.00	4.18	.82	1.20
B — ILS_2	4.50	3.95	.55	1.40
C — ILS_1	4.00	3.72	.28	1.08
D — ILS_2	3.00	3.59	-.59	.84

A special UAV application is an exception to the general preference for NPV. In those situations where the alternative methods of accomplishing the objective have unequal lives and (1) the cost estimates associated with the lifetime of any particular alternative may be repeated in the future for as many lifetimes as required and (2) the period of required services is either indefinitely long or of a length of time equal to a common multiple of the various alternatives, the UAV method can be used to determine which alternative is best. This requires that the difference between uniform annual benefits and costs be computed as indicated in equation (5-11). Where benefits are identical for all alternatives, the same result may be obtained by computing only uniform annual costs and selecting the lowest. It should be noted that where the objective requires provision of a service to a specific future date, the UAV method should not be used. Rather, the NPV method should be computed for each alternative over the required time period.

D. Internal Rate of Return

The internal rate of return (IRR) is defined as that discount rate which equates the present value of the stream of expected benefits in excess of cost to zero. In other words, it is the highest discount rate at which the project will not have a negative NPV. To apply the criterion, it is necessary to compute the IRR and then compare it with OMB prescribed 10 percent discount rate. If the IRR is greater than or equal to 10 percent the project should be undertaken for its NPV is non-negative. If the IRR is less than 10 percent, the project has a negative NPV and should not be undertaken.

While the IRR method is effective in deciding whether or not a project is worth undertaking, it is difficult to utilize in ranking projects and in deciding between competing mutually exclusive alternatives. It is not unusual for ranking established by the IRR method to be inconsistent with those of the NPV criterion. Moreover, it is possible for a project to have more than one IRR. Although the literature on capital budgeting contains solutions to these problems, these are often complicated or difficult to employ in practice and present opportunities for error. As a consequence, it is not recommended that the IRR method be used for FAA investment or decision-making purposes. [4/]

4/ See G. David Quirin, The Capital Expenditure Decision, Richard D. Irwin, Inc., Homewood Illinois 1967, pp. 46-55, and Jack Hirshleifer, Investment, Interest, and Capital, Prentice-Hall, Inc., Englewood Cliffs, N.J., pp.71-80.

CHAPTER 6

SENSITIVITY ANALYSIS

I. Concept of Sensitivity Analysis

The outcome of an analysis will depend on numerous estimates, forecasts, assumptions, and approximations to reality. Each of these factors has the potential to introduce error into the results. The importance of such errors in affecting the outcome of the analysis must be known to the decisionmaker if informed decisions are to be made and confidence placed in such decisions. Moreover, the degree of uncertainty associated with each alternative is itself a factor to be considered in selecting between competing alternatives. This chapter presents methodology, known as sensitivity analysis, for dealing with the imprecision and uncertainty characterizing most economic analyses of proposed investment projects and regulations.

The basic approach is to vary key assumptions, estimates, and forecasts systematically over appropriate ranges and observe the impact on the results. For certain items, the impact may be insignificant while for others it may be quite large. In some cases the relative desirability of competing alternatives may be altered while in others it will not be. The actual procedure for varying a parameter depends on whether or not it

may be described by a known probability distribution or not. If so, probability statements can be made about each value selected and the outcome of the analysis. Such an approach is known by convention as risk analysis. If the probability distribution for each parameter is not known, alternative values of the parameter are selected over a range over which it is known or believed reasonable for it to vary. Probability statements regarding the likely occurrence of any particular value of the parameter are not possible. This approach is known as uncertainty analysis.

There are several ways in which the analysis can be accomplished. Each depends on how the key assumptions, estimates, and forecasts are varied. One procedure is to vary only one at a time, holding the others constant so as to determine the independent, or partial, effect of this parameter. This procedure is known as a one variable uncertainty test. A second procedure is to vary two parameters simultaneously and is known as a two variable uncertainty test. Similarly, three, four and more variable uncertainty tests can be constructed. These can easily produce large amounts of data and require the decisionmaker to consider an excessively large number of outcomes. An alternative is to allow all parameters to vary together in several predetermined patterns, each representing a relevant probable future state of affairs. This procedure is known as alternative scenario analysis. The following sections will examine one and two variable uncertainty analysis and alternative scenario analysis.

II. One Variable Test

This procedure should be applied to the major cost and benefit components of each alternative. Its primary purpose is to identify the sensitivity of the net present value of each alternative to changes in value of each component. This permits additional effort to be devoted to improving the reliability of estimates for those components to which the results are sensitive. Where reliability cannot be improved, it puts the decisionmaker on notice as to potential weaknesses of the economic analysis.

To carry out the one variable tests, the NPV of each alternative must be recalculated for different values of any one particular component while the others are held constant. The range of values should extend over those that can reasonably be expected to prevail. Where a probability distribution for the component of interest is known, this range may be established by a confidence interval (usually 90 or 95 percent). Where such a distribution is unknown, the range should extend from the smallest to the largest value that could reasonably be expected to occur. The process should be repeated for each major component to be tested.

Once these computations have been completed, the problem arises as to how to display the results. If only a small number of components were tested, a tabular display may be appropriate. If more components were varied, a graphical display is often useful. Consider the following

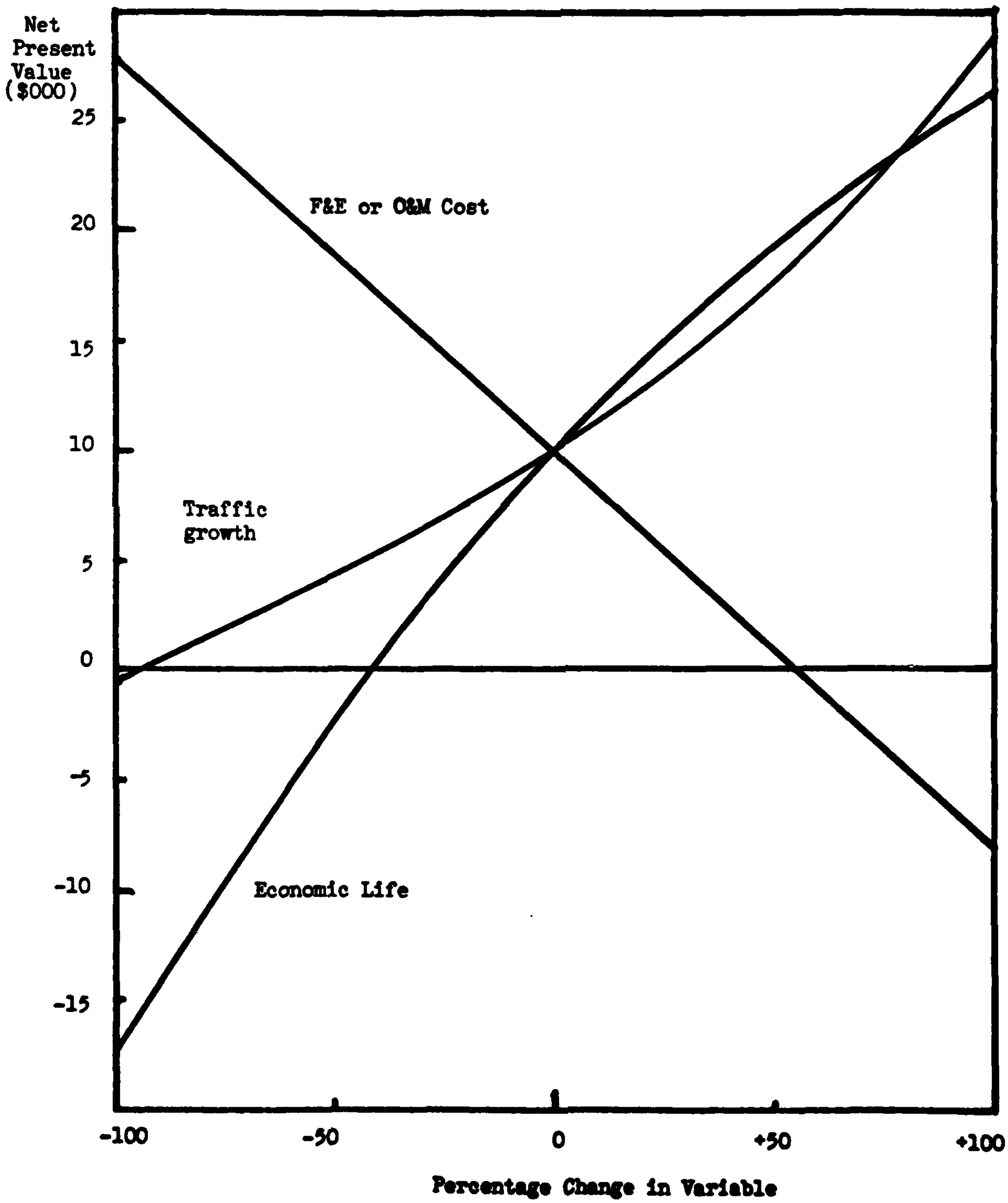
example of a Runway End Identifier Light (REIL) system. Estimates indicate that installation of the system on a particular runway will generate benefits and costs over a 15 year economic life with present values of $45,430 and $35,430, respectively, for a net present value of $10,000.[1/] These estimates are based on four basic forecast variables: traffic growth, economic life, facilities and equipment cost, and operations and maintenance cost. Figure 6-1 indicates the impact on NPV that will occur if each of these items is allowed to vary over a range of plus or minus 100 percent while the others are held constant. (Note that the F&E line and the O&M line approximately coincide and are represented as a single line in the figure. This is merely a coincidence and will not happen in general.)

As can be seen, increases in F&E or O&M costs of about 55 percent will result in a negative NPV indicating that the project should not be undertaken. Shortening the economic life by about 55 percent will also result in the NPV becoming negative. Changes in traffic growth will not effect the desirability of the project unless projected growth declines by about 90 percent. From this information, the decisionmaker can conclude that the project will have a positive NPV unless there are substantial changes in the key variables.

1/ Estimates based on data contained in "Establishment Criteria For Runway End Identification Lights (REIL)," FAA-ASP-79-4, U.S. Department of Transportation, November 1979.

FIGURE 6-1

ONE VARIABLE UNCERTAINTY TEST



III. Two Variable Test

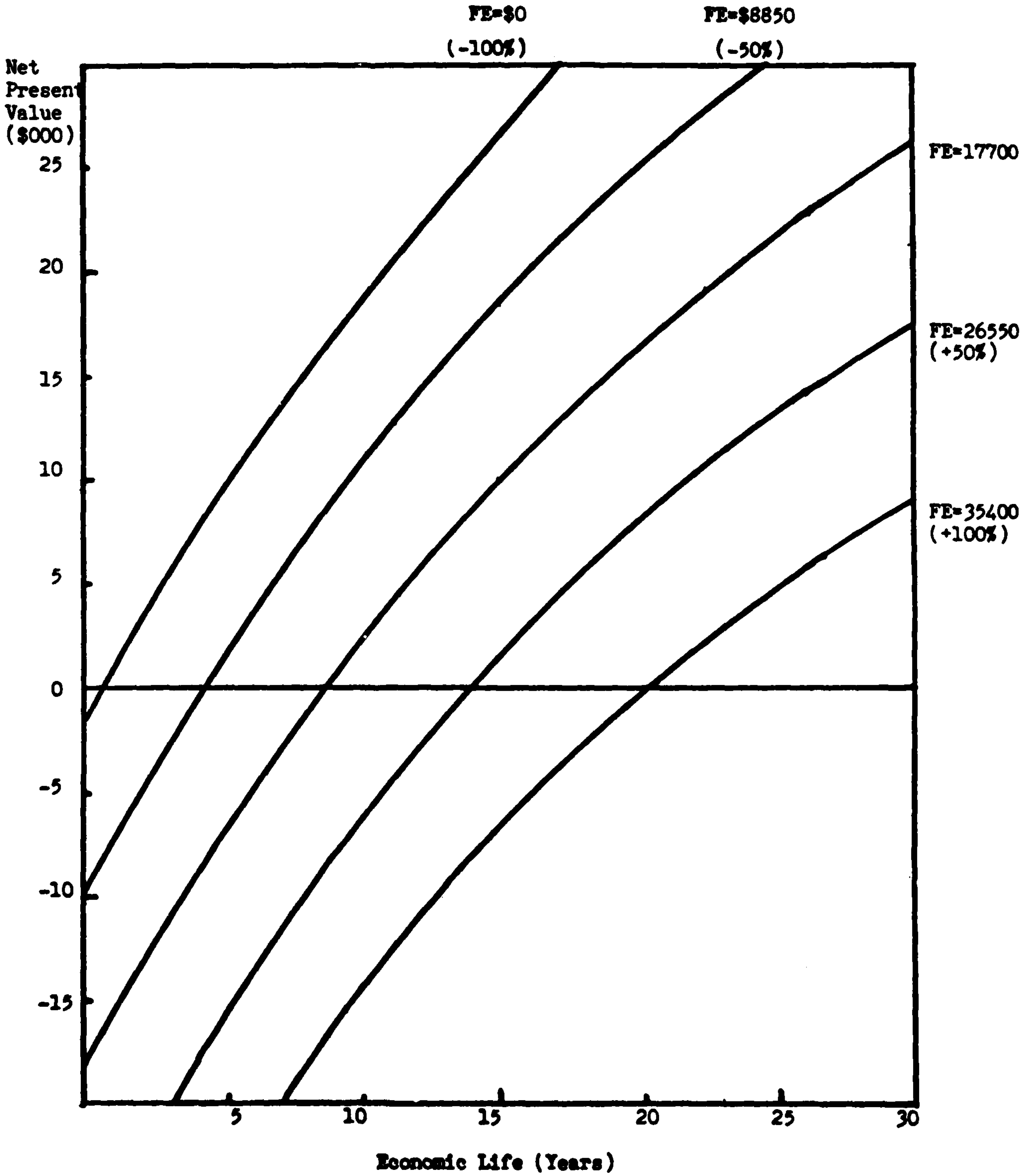
The one variable test permits examination of one factor holding all others constant. At times it may be useful to let two factors change at the same time. Such changes may be expected to occur together. Or it may be necessary to determine the extent to which a change in one factor can be offset by a change in another. Again, consider the REIL example, but let both economic life and F&E cost vary together.

As indicated in Figure 6-2, a different curve relating NPV to economic life may be constructed for each different level of F&E spending. For any given NPV, it is clear that an increase in F&E cost requires a longer economic life. Specifically, to maintain an NPV of $10,000 in the face of a 50 percent increase in F&E cost from $17,700 to $26,550 requires that the economic life be extended 7 years to 22 years. Similarly, a decrease in F&E cost of 50 percent to $8,850 permits a reduced economic life of 9 years while maintaining a NPV of $10,000.

A useful application of this information would be in deciding between two quality levels of a proposed REIL installation, the existing one and a hypothetical one of higher quality expected to provide a longer economic life. If the higher quality one had a higher initial price of $26,550 (50 percent greater than the existing standard of $17,700), it would have to have an expected economic life of at least 22 years for it to be accepted in place of the standard. If the life were less than 22 years, the NPV associated with the higher quality system would be less than that of the standard system.

FIGURE 6-2

TWO VARIABLE UNCERTAINTY TEST



IV. Alternative Scenarios

The two variable test, above, is a special case of a multiple variable test. Consider the following abstract case:

$$NPV = f\ (X_1, X_2, X_3, \ldots, X_n) \tag{6-1}$$

Where X_i = all the n key variables and

f = a function relating the key variables to net present value.

In the two variable case, two of the X_i's are allowed to vary while the others are held constant. Multiple variable tests could instead be carried out by solving (6-1) for large numbers of combinations of values for all of the X_i's. While possible, so many values for NPV would be generated that it would be difficult if not impossible to deal with them. An alternative procedure is to select several combinations of the X_i's and evaluate these. Each such combination is known as a scenario.

Scenarios should be designed to cover the entire range of likely outcomes. The range of outcomes should be bounded by a most favorable and a worst possible scenario. Intermediate ones should be designed for other outcomes. If possible, one of these should be designated as most likely. In addition, if sufficient information is available, probabilities may be assigned to each scenario.

Because each scenario represents a potential outcome, the combination of X values that define a scenario should be consistent with each other. (If they are not, then the scenario does not represent a possible outcome.) While it is impossible to determine and avoid all possible inconsistencies, obvious ones can be avoided. In the example of the REIL system, it would not be reasonable to define a scenario in which traffic (and thus benefits) was substantially above current forecasts and operating cost (electricity and transportation) also increased substantially as a result of oil price increases. Such oil price increases could be expected to increase the cost of flying, which could be expected to restrict traffic growth, not increase it.

The FAA Aviation Forecasts [2/] makes projections of aviation activity under four alternative scenarios: (1) Baseline, (2) Wharton Econometric Forecast, (3) Economic Expansion, and (4) Stagflation. Each is based on a different set of economic and social factors. The Baseline represents the current Administration's economic assumptions. The intent of the others is to reflect what could happen to aviation if the determining economic and social forces should deviate from those underlying the Baseline. These scenarios may be useful in generating alternative benefit estimates for proposed investments and regulations.

2/ FAA Aviation Forecasts, U.S. Department of Transportation, current year.

CHAPTER 7

INFLATION

I. Introduction

The performance of economic analysis requires that benefits and costs be measured. The yardstick of measurement is the dollar. This yardstick must remain unchanged for all quantities measured if resulting measurements are to be meaningful and comparable with each other. But the value of the dollar is rarely constant from one year to the next. Changes in the prices of goods and services continuously effect the purchasing power of the dollar. This chapter deals with how to correct for changes in the value of the dollar over time in order that the same yardstick of value can be applied to benefits and costs occurring in different years.

II. Measuring Inflation

Changes in the value of the dollar over time with respect to any particular commodity or group of commodities are measured using an index number. Such a number is a measure of relative value. It indicates the price of any particular commodity or group of commodities in one year relative to its value in some other year. By convention, index numbers are usually computed as the ratio of this price in one year divided by the price in the base year. The resulting ratio is then multiplied by 100 to produce the index number. Repeating the process for a number of years results in a series of index numbers.

To grasp the methodology of working with index numbers, consider the Gross National Product (GNP) Implicit Price Deflator, which is reported in Table 7-1 for 1970 through 1980. Note first that 1972 has a value of 100. Known as the base year, it is an arbitrary selection which is changed from time to time. It indicates that all other values are

TABLE 7-1

GROSS NATIONAL PRODUCT IMPLICIT PRICE DEFLATOR
(1970 - 1980)

Year	Index
1970	91.45
1971	96.01
1972	100.00
1973	105.69
1974	114.92
1975	125.56
1976	132.11
1977	139.83
1978	150.05
1979	162.77
1980	177.36

Source: Survey of Current Business, Bureau of Economic Analysis, Department of Commerce, Published monthly.

measured relative to 1972 being equal to 100. For example the 1977 value of the index of 139.83 means that the price level in 1977 was 39.83 percent higher than it was in 1972, which is readily apparent from inspection. It is not readily apparent, however, how much greater the 1979 price level is than it was in 1970. This can be easily computed as 78.0 percent by dividing the 1979 value by the 1970 value: 162.77/91.45 = 1.780. Moreover, the entire index may be restated in terms of any other

base year by dividing each value by that of the new base year. Annual changes may be computed by dividing each value by that of the previous year and subtracting unity. For example, the rate of price change between 1975 and 1974 is: (125.56/114.92)-1 = 9.26%.

To make adjustments for price level changes requires that the concepts of constant dollars and current dollars be understood. Current dollar estimates are expressed in the price level of the year in which the resource flows they represent occur. They are the actual amount spent or received. Constant dollar estimates represent the same value as current dollar estimates but as measured by the yardstick of the price level of a fixed reference year. Constant dollars can be specified in terms of any reference year that is desired.

To convert a series expressed in current dollars to constant dollars of a particular year requires that all numbers in the series be adjusted for price level changes except the one that actually occurred in the year of the dollars to which the adjustment is being made. This requires two steps. First the price index must be transformed so that its year is the one in which the constant dollars are to be stated. As previously noted, this is accomplished by dividing the price index through by its value in the desired base year. The second step is to convert the subject series to constant dollars. This requires that it be divided by the values produced by step 1. The procedure, as applied to the FAA budget appropriation, is illustrated in Table 7-2. To convert constant dollars to current dollars requires that the procedure be reversed. First the

deflator series must be divided by its value in the year in which the constant dollars are expressed and multiplied by the constant dollar series.

TABLE 7-2

CONVERSION OF FAA APPROPRIATIONS FROM CURRENT DOLLARS TO CONSTANT 1975 DOLLARS (dollars in millions)

Year	(1) GNP Deflator (1972=100)	(2) a/ GNP Deflator (1975=100)	(3) Appropriations in current Dollars	(4) b/ Appropriations in 1975 Constant Dollars
1970	91.45	72.83	1,288	1769
1971	96.01	76.47	1,787	2337
1972	100.00	79.64	1,901	2387
1973	105.69	84.17	1,852	2200
1974	114.92	91.53	1,935	2114
1975	125.56	100.00	2,078	2078
1976	132.11	105.22	2,274	2161
1977	139.83	111.37	2,566	2295
1978	150.05	119.50	2,793	2337
1979	162.77	129.64	3,150	2430
1980	177.36	141.26	3,274	2318

Source: Survey of Current Business, Bureau of Economic Analysis, Department of Commerce, published monthly, and FAA Statistical Handbook, Federal Aviation Administration, Calendar Year 1979, Table 1.1.

a/ Divide column (1) by 125.56 and multiply by 100.
b/ Column (3) divided by (column (2)/100).

Another conversion likely to be encountered in practice is the transformation of a series from the constant dollars of one year to those of another. This is easily accomplished by multiplying the constant dollar

series by the ratio of the price index term for the desired year to the price index term for the year in which it is currently expressed, where the base year of the price index is arbitrary. For example, to convert the 1975 constant dollar series in column (4) of Table 7-2 from 1975 constant dollars to 1979 constant dollars requires that each number in it be multiplied by 129.64/100 (or 162.77/125.56).

III. Sources of Price Indexes

Numerous different price indexes are published by private and governmental organizations. They are available for many narrowly defined commodities and services as well as for broader classifications ranging in scope from selected 4-digit SIC Code 1/ industries up to the overall economy. This section identifies several indexes that may be of use to agency analysts. They are organized by categories relevant to potential FAA economic analyses. These indexes are intended only as suggestions. Available information and the specific situation should govern the actual indexes selected for any particular inflation adjustment problem.

1/ Industries are classified by the Standard Industrial Classification Manual 1972, Office of Management and Budget, 1972. The classification system operates in such a way that the definitions become progressively narrower with successive additions of numerical digits. The broadest classifications contain 2 digits and the narrowest 7 digits.

A. General Price Level

The Gross National Product (GNP) Implicit Price Deflator represents changes in the prices of all goods and services produced in the United States. 2/ Because of its broad coverage, it is widely regarded as the best single measure of changes in the general price level. It is compiled by the Department of Commerce. Data for the most recent three years are published in the Survey of Current Business; 3/ older data are reprinted in Business Statistics. 4/ The entire series is also reprinted annually in the Economic Report of the President. 5/

B. Economic Sector Price Levels

Price levels of sectors of the economy represented by the various components of Gross National Product are measured by the respective deflator for each component. Component deflators likely to be of interest to agency analysts are those for fixed investment, nonresidential structures, and government purchases of goods and services. These component deflators are published in the same sources as the GNP deflator.

2/ Technically, the GNP Implicit Deflator is not a conventional price index. It is not computed by pricing a standardized assortment of goods and services i. two different time periods. Rather, it is the ratio of current GNP valued at today's prices divided by current GNP valued in the prices of the previous year.

3/ Survey of Current Business, Bureau of Economic Analysis, Department of Commerce, Washington, D.C., published monthly.

4/ 1977 Business Statistics, Bureau of Economic Analysis, Department of Commerce, Washington, D.C., March 1978.

5/ Economic Report of the President, Council of Economic Advisers, Washington, D.C., published annually in January.

C. Construction

Several widely known indexes of construction costs are available in addition to the implicit deflator for investment in nonresidential structures. The Boeckh indexes are compiled monthly by the American Appraisal Company. They represent construction costs for three types of buildings: (1) apartments, hotels, and office buildings, (2) commercial and factory buildings, and (3) residences. The Engineering-News Record publishes monthly its Building Cost Index. It represents the price of constant quantities of skilled labor, structural steel, lumber, and cement.[6/] It is available separately for 20 U.S. cities and each December is forecast for the next twelve months.

The Federal Highway Administration publishes a quarterly index of highway construction costs. It is based on pricing of three components of highway construction: common excavation, surfacing, and structures. All of these indexes are reproduced in the Survey of Current Business. In addition, the Department of Commerce publishes a composite construction index of these and others. [7/]

6/ For a detailed description of the index, see "Materials and Labor Cost Trends in the U.S., Engineering News-Record, (March 19, 1981) pp. 132-137.

7/ For a summary of the details relating to each of these indexes, see Business Statistics, 1977 Edition, Department of Commerce, March 1978, pp. 56-57 of the Explanatory Notes to the Statistical Series.

D. Energy

As a component of the Producer Price Index, the Bureau of Labor Statistics compiles monthly indexes for the prices of coal, coke, gas fuels, electric power, crude petroleum, and refined petroleum products, as well as a composite of them. These are published in The Monthly Labor Review. 8/

E. Electronics

Also contained in the Producer Price Indexes are several components representing electric and electronic devices. The broadest category is for electrical machinery and equipment. It represents such items as wiring devices, instruments, motors, transformers, switching gear, electric lamps, and electronic components and accessories. An index for each of these subcomponents is also available. The electric and electronic devices index is published in the Monthly Labor Review and the subcomponent indexes in Producer Prices and Price Indexes. 9/ In addition, indexes for specific SIC electronics industries--electron receiving tubes (SIC Code=3671), semiconductors (SIC Code=3674), electronic capacitors (SIC Code=3675), electronic resistors (SIC Code=3676), and electronic connectors (SIC Code=3678)--are also provided in each of these publications.

8/ The Monthly Labor Review, Bureau of Labor Statistics, Department of Labor, published monthly.

9/ Producer Prices and Price Indexes, Bureau of Labor Statistics, Department of Labor, published monthly.

IV. Treatment of Inflation in Benefit-Cost Analysis

As a general rule, inflation should not be permitted to affect the outcome of benefit-cost analyses. Such studies are concerned with real quantities--resources consumed and benefits provided. The dollar is used only as the yardstick of value measurement. Because changes in the unit of measurement cannot affect the relationship between the real quantities, allowing price changes to enter the analysis will distort the results. This section presents methodology for ensuring that inflation does not enter benefit-cost analyses and produce such distortions.

A. Period Between Analysis Date and Project Start Date

The selection of the yardstick of value measurement is arbitrary. The constant dollars of one year are as good as the constant dollars of any other year as far as the economics of the analysis goes. However, for practical considerations it is recommended that the constant dollars of the year of the analysis be selected as the unit of measurement. This procedure is a natural approach because it permits benefits and costs to be valued at their current prices. Moreover, it avoids the need to transform current prices into past or future year dollars and, with respect to future years, the need to forecast inflation. Note that this recommendation is not a hard and fast rule and should not be followed when other circumstances so indicate.

B. Inflation During Project Life

During the projected life of the proposed investment or regulation, changes in the general level of prices should not be allowed to impact the analysis. Benefits and costs are real quantities; they consist of the goods and services provided by a project and the resources consumed in providing them. Dollars enter the analysis only as the yardstick of value. To allow the unit of measurement to vary would assign different valuation to the same benefits or costs depending on the variation in the unit of measurement over the project's lifetime. With the typical investment or regulation during times of increasing prices, large costs occurring early in the project's life would be assigned less value than benefits stretching out over the years. This could lead to projects being undertaken which are not worthwhile because inflation had been allowed to increase benefit values relative to cost values. To avoid such distortions, all benefits and costs associated with an investment or regulation must be measured in the constant dollars of a particular year—preferably the year of the analysis for reasons noted in section IV-A of this chapter.

There is an important qualification (not exception) to the general rule of expressing all quantities in the constant dollars of a particular year. Quantities that increase or decrease in value more or less than the general

price level should have their values adjusted by the difference between changes in their value and the general price level. This must be done to reflect that their real values in comparison with other goods and services have changed in addition to any changes in the general level of prices.

Adjustment for real price changes requires that the difference between forecast general price level changes and prices of the items in question be computed. This may be accomplished by taking the ratio of the specific item price index to the GNP deflator. The resultant index will show how much the specific item is forecast to increase or decrease in price once the impact of overall price level changes is removed. This resultant index may then be multiplied by the constant dollar estimate of the item in question in each year to adjust it for real changes in value. This procedure is demonstrated by equations (7-1) and (7-2):

$$RI_t = \frac{SPI_t}{GNPI_t} \qquad (7\text{-}1)$$

$$XA_t = XO_t(RI_t) \qquad (7\text{-}2)$$

Where: SPI_t = specific item price index in year t,
$GNPI_t$ = implicit GNP deflator in year t,
RI_t = resultant index in year t
XO_t = unadjusted value, and
XA_t = value adjusted for real price changes.

In practice, another procedure is often used. If a particular item is known to be changing in real value at an approximately constant rate, its value may be projected by equation (7-3):

$$XA_t = XO_t(1 + f)^m \qquad (7\text{-}3)$$

Where: m = the number of years between year t and the year in which the constant dollars of measurement are stated, and
f = the annual rate of real growth.

This adjustment can be combined with the discounting procedure developed in Chapter 5 and defined in equation (5-6). Combination is possible because two ratios are being applied similarly to the same benefit or cost figure. This is indicated in equation (7-4):

$$NPV = \sum_{t=o}^{k} \frac{(B-C)'}{(1+r)^t} + \sum_{t=o}^{k} X_t \left[\frac{1+f}{1+r}\right]^t \qquad (7\text{-}4)$$

Where: X_t = the quantity being adjusted expressed in constant dollars of the year of initial project implementation, and

$(B-C)'$ = all benefits and costs other than those contained in X_t.

A typical situation where real cost changes must be considered arises with respect to replacement projects. One advantage of the proposed new system over the old often is that it replaces an old technology with a new one. In cases where the real cost of the old technology is projected to increase with time, the absolute amount of the new system's advantage continually increases. While it is proper to include such an ever increasing advantage

in an evaluation, the burden of establishing an appropriate rate of increase rests squarely on the shoulders of the analyst. Conclusions which result solely from assuming large real cost increases in the existing system which are not thoroughly justified are not convincing and are easily contested.

APPENDIX A

DOCUMENTS REQUIRING ECONOMIC ANALYSIS

The requirement to conduct economic analyses of investment projects and regulatory actions is documented in the following Executive Orders, Office of Management and Budget (OMB) Circulars, DOT Orders, and FAA Orders.

A. INVESTMENT PROJECTS

1. OMB CIRCULAR A-94 (Revised) (March 27, 1972): "Discount Rates to be Used in Evaluating Time-Distributed Costs and Benefits"--Prescribes methodology to be used in evaluating time-distributed benefits and costs. The circular requires that present values for such benefits and costs be calculated using a 10 percent discount rate. It also establishes policy for the treatment of inflation and changes in real costs. The circular applies to the evaluation of U.S. Government programs and projects; it does not apply to the evaluation of decisions regarding acquisition of commercial-type services by Government or contractor operations (guidance for which is provided in OMB Circular A-76 (Revised)).

2. OMB CIRCULAR A-104 (June 14, 1972): "Comparative Cost Analysis for Decisions to Lease or Purchase General Purpose Real Property"--Prescribes the economic basis for determining whether general purpose real property to be acquired for government programs should be leased or purchased. It applies to the acquisition of general purpose real property such as office buildings, warehouses, and associated land for which estimated land and construction costs or market value is $500,000 or more. From a practical point of view, this circular will apply to very few FAA lease vs. purchase decisions. Most such FAA decisions are under $500,000.

3. <u>OMB CIRCULAR A-109 (April 5, 1976)</u>: "Major System Acquisitions"--Establishes policies to be followed by executive agencies in the acquisition of major systems. These include a well defined management process with clear lines of authority, responsibility, and accountability for major system acquisitions. Among other policies set out are those requiring formulation of alternatives to achieve agency objectives, life cycle costing techniques, and assessment of anticipated benefits.

4. <u>ORDER DOT 4200.14A (May 17, 1978)</u>: "Major Systems Acquisition Review and Approval"--Prescribes the procedures for implementing OMB Circular A-109. This order is applicable to all acquisitions "that (1) are directed at, and are critical to, fulfilling a Departmental mission, (2) entail the allocation of relatively large resources, and (3) warrant special management attention, . . . or which have a total acqusition cost of $150 million or more, or which have an anticipated total expenditure of $25 million or more in research and development funds." The order specifically requires that benefit-cost analysis, or cost-effectiveness analysis, be undertaken for each acquisition subject to the requirements of this order. The order further specifies that in determining the costs of a major system, life cycle costing methodology shall be used.

5. ORDER DOT 4200.9A (August 29, 1978): "Acquisition Review and Approval"—Establishes DOT policy and procedures for Secretarial review of acquisitions which are smaller than major system acquisitions and not subject to the detailed management requirements of Order DOT 4200.14A and OMB Circular A-109. The order applies to all acquisitions funded by DOT which meet the criterion set forth in Order DOT 4200.14A, paragraph 5(a), (detailed above) except for the specified dollar levels. Acquisitions with anticipated costs below those specified in Order DOT 4200.14A and above $20 million or with a three year total expenditure on research and development of more than $5 million are subject to this order. Although concerned with smaller projects, this order requires the consideration of benefit-cost analysis as part of the acquisition process.

6. ORDER FAA 1810.1B (November 21, 1980): "System Acquisition Management"--Establishes policy and procedures for system acquisition management and implements Order DOT 4200.9A, Acquisition Review and Approval and Order DOT 4200.14A, Major Systems Acquisition Review and Approval. This order specifically requires that benefit-cost analysis be undertaken for every acquisition subject to Order DOT 4200.9A and Order DOT 4200.14A, as well as other programs designated by the Administrator.

B. REGULATORY ACTIONS

1. <u>REGULATORY FLEXIBILITY ACT OF 1980</u>--Requires agencies to publish an Initial Regulatory Flexibility Analysis, or summary of it, in the <u>Federal Register</u> for any regulatory action requiring a Notice of Proposed Rulemaking at the time the notice is published. The Act further requires that agencies publish a Final Regulatory Flexibility Analysis at the time the final rule is published. These requirements can be avoided in those situations where the head of the agency "certifies that the rule will not, if promulgated, have [1] a significant economic impact on [2] a substantial number of [3] small entities," where small entities are defined as small businesses, small organizations, and small government jurisdictions. The act also requires agencies to review within a one year period regulations in effect on January 1, 1981 which have a significant economic impact on a substantial number of small entities.

2. <u>EXECUTIVE ORDER 12291 (February 17, 1981)</u>: "Federal Regulation"--Requires agencies when reviewing existing regulations, promulgating new regulations, and developing legislative proposals concerning regulations to base their actions on adequate information concerning the need for and consequences of proposed government action and to undertake or sustain only those regulations for which the potential benefits to society exceed the potential costs to society. Moreover, the order indicates that agencies shall take regulatory actions and

set regulatory policies so as to maximize the aggregrate net benefits to society. The order further prescribes that each agency shall prepare a Regulatory Impact Analysis (RIA) in connection with every major rule, where major rule is defined as any regulation that is likely to result in: (1) an annual effect on the economy of $100 million or more, (2) a major increase in costs or prices of goods and services, or (3) significant adverse effects on competition, employment, investment, productivity, innovation, or on the ability of United States-based enterprises to compete with foreign-based enterprises in domestic or export markets. Such analysis is required to be based upon the benefits and costs of the proposed rule. It may be combined with any Regulatory Flexibility Analysis required by the Regulatory Flexibility Act.

3. OMB INTERIM REGULATORY IMPACT ANALYSIS GUIDANCE: (June 12, 1981)--
Provides guidance for conducting the Regulatory Impact Analysis required by Executive Order 12291. It indicates that to meet the requirements of the Executive Order, an RIA must show that: "(1) there is adequate information concerning the need for and consequences of the proposed actions, (2) the potential benefits to society outweigh the potential costs, and (3) of all the alternative approaches to the given regulatory objective, the proposed action will maximize net benefits to society." It further indicates that to be judged satisfactory, an RIA should enable independent reviewers to determine

that the objectives of Executive Order 12291 have been satisfied. RIA's should contain five parts: (1) a statement of the need for and consequences of the proposed regulation, (2) an examination of the most important alternative approaches to the problem; (3) an analysis of benefits and costs; (4) a rationale for choosing the proposed regulatory action; and (5) a statement that the proposed regulatory action is within the agency's statutory authority.

4. ORDER DOT 2100.5 (May 22, 1980): "Policies and Procedures for Simplification, Analysis, and Review of Regulations"--Establishes requirements that a regulatory analysis be conducted for essentially all regulations for which Executive Order 12291 requires a Regulatory Impact Analysis and that a regulatory evaluation be conducted for all other regulations. It defines a regulatory analysis as containing "(1) a succinct statement of the problem and issues that make the regulation significant; (2) a description of the major alternative ways of dealing with the problem that were considered by the initiating office; (3) an analysis of the economic and any other relevant consequences of each of these alternatives; and (4) a detailed explanation of the reason for choosing one alternative over the others." A regulatory evaluation "includes an analysis of the economic consequences of the proposed regulation quantifying to the extent practicable, its estimated cost to the private sector, consumers, Federal, state and local governments, as well as its anticipated benefits and impacts."

APPENDIX B

STANDARDIZED VALUES FOR USE IN EVALUATING FAA INVESTMENTS AND REGULATORY ACTIONS

Table B-1 of this appendix summarizes values for use in valuing the benefits of proposed FAA investment projects and regulatory actions. These values are developed in detail in Ward L. Keech, Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs, Report No. FAA-APO-81-3, Office of Aviation Policy and Plans, Federal Aviation Administration, September 1981. They are intended to represent minimum estimates of the dollar amounts which society as a whole--that is, all parties whether public or private--would be willing to sacrifice for each of the specified items. For example, the values in the table indicate that society as a whole would be willing to pay at least $530,000 to save a statistical life and $81 to save an hour of general aviation aircraft operating time. Incorporation of these values into benefit estimation is explained in Chapter 3.

TABLE B-1

STANDARDIZED VALUES FOR USE IN EVALUATING
FAA INVESTMENTS AND REGULATORY ACTIONS

(1980 Dollars)

Item	Value
Value of Time of Air Travelers Per Hour	$ 17.50
Value of a Statistical Life	$530,000
Unit Cost of Statistical Aviation Injuries:	
Serious Injury	$ 38,000
Minor Injury	$ 15,000

Unit Replacement/Restoration Cost of Damaged Aircraft (Replacement or Destroyed/Restoration or Substantial Damage):	Replacement Cost	Restoration Cost
Air Carrier:		
- Turbofan, 4 Engine, Wide Body	$20,500,000	$6,800,000
- Turbojet, 4 Engine	$ 1,600,000	$ 530,000
- Turbofan, 4 Engine, Regular Body	$ 4,000,000	$1,300,000
- Turbofan, 3 Engine, Wide Body	$20,500,000	$6,700,000
- Turbofan, 3 Engine, Regular Body	$ 4,000,000	$1,300,000
- Turbofan, 2 Engine, Wide Body	$20,000,000	$6,700,000
- Turbofan, 2 Engine, Regular Body	$ 5,100,000	$1,700,000
- Turboprop, 2 Engine	$ 1,300,000	$ 430,000
- Piston, 2 Engine	$ 300,000	$ 100,000
- *Weighted Average*	$ 6,200,000	$2,100,000
General Aviation:		
- General Aviation including Air Taxi other than Air Commuter	$ 58,000	$ 19,000
- General Aviation excluding Air Taxi	$ 56,000	$ 19,000
- Air Taxi	$ 137,000	$ 46,000
- Air Taxi other than Air Commuter	$ 120,000	$ 40,000
- Air Commuter	$ 213,000	$ 71,000
- Weighted Average, representing General Aviation in the conventional sense (including Air Taxi and Air Commuter)	$ 59,000	$ 20,000
Military:		
- Fixed-Wing	$ 2,200,000	$ 730,000
- Rotary-Wing	$ 410,000	$ 140,000
- Weighted Average	$ 1,400,000	$ 470,000

Aircraft Variable Operating Costs:	Per Block Hr.	Per Airborne Hr.
Air Carrier:		
- Turbofan, 4 Engine, Wide Body	$ 4,327	$ 4,767
- Turbojet, 4 Engine	$ 2,483	$ 2,880
- Turbofan, 4 Engine, Regular Body	$ 2,295	$ 2,643
- Turbofan, 3 Engine, Wide Body	$ 2,897	$ 3,341
- Turbofan, 3 Engine, Regular Body	$ 1,641	$ 1,964
- Turbofan, 2 Engine, Wide Body	$ 2,155	$ 2,655
- Turbofan, 2 Engine, Regular Body	$ 1,219	$ 1,508
- Turboprop, 2 Engine	$ 546	$ 694
- Piston, 2 Engine	$ 136	$ 139
- Weighted Average	$ 1,871	$ 2,229
General Aviation:		
- General Aviation including Air Taxi other than Air Commuter		$ 79
- General Aviation excluding Air Taxi		$ 73
- Air Taxi		$ 163
- Air Taxi other than Air Commuter		$ 145
- Air Commuter		$ 278
- Weighted Average, representing General Aviation in the conventional sense (including Air Taxi and Air Commuter)		$ 81
Military:		
- Turbojet/fan, Multi-engine		$ 2,339
- Turbojet/fan, Twin-engine		$ 1,319
- Turbojet/fan, Single-engine		$ 872
- Turboprop		$ 360
- Piston		$ 97
- Rotary-Wing		$ 113
- Weighted Average		$ 661

APPENDIX C

PRESENT VALUE TABLES

TABLE C-1

PRESENT VALUE OF $1 FLOWING AT THE END OF THE PERIOD

(Discrete Compounding)

Period	Annual Effective Discount Rate 2%	5%	8%	10%a/	12%	15%	20%
1.	.9804	.9524	.9259	.9091	.8929	.8696	.8333
2.	.9612	.9070	.8573	.8264	.7972	.7561	.6944
3.	.9423	.8638	.7938	.7513	.7118	.6575	.5787
4.	.9238	.8227	.7350	.6830	.6355	.5718	.4823
5.	.9057	.7835	.6806	.6209	.5674	.4972	.4019
6.	.8880	.7462	.6302	.5645	.5066	.4323	.3349
7.	.8706	.7107	.5835	.5132	.4523	.3759	.2791
8.	.8535	.6768	.5403	.4665	.4039	.3269	.2326
9.	.8368	.6446	.5002	.4241	.3606	.2843	.1938
10.	.8203	.6139	.4632	.3855	.3220	.2472	.1615
11.	.8043	.5847	.4289	.3505	.2875	.2149	.1346
12.	.7885	.5568	.3971	.3186	.2567	.1869	.1122
13.	.7730	.5303	.3677	.2897	.2292	.1625	.0935
14.	.7579	.5051	.3405	.2633	.2046	.1413	.0779
15.	.7430	.4810	.3152	.2394	.1827	.1229	.0649
16.	.7284	.4581	.2919	.2176	.1631	.1069	.0541
17.	.7142	.4363	.2703	.1978	.1456	.0929	.0451
18.	.7002	.4155	.2502	.1799	.1300	.0808	.0376
19.	.6864	.3957	.2317	.1635	.1161	.0703	.0313
20.	.6730	.3769	.2145	.1486	.1037	.0611	.0261
21.	.6598	.3589	.1987	.1351	.0926	.0531	.0217
22.	.6468	.3418	.1839	.1228	.0826	.0462	.0181
23.	.6342	.3256	.1703	.1117	.0738	.0402	.0151
24.	.6217	.3101	.1577	.1015	.0659	.0349	.0126
25.	.6095	.2953	.1460	.0923	.0588	.0304	.0105
26.	.5976	.2812	.1352	.0893	.0525	.0264	.0087
27.	.5859	.2678	.1252	.0763	.0469	.0230	.0073
28.	.5744	.2551	.1159	.0693	.0419	.0200	.0061
29.	.5631	.2429	.1073	.0630	.0374	.0174	.0051
30.	.5521	.2314	.0994	.0573	.0334	.0151	.0042

a/ Discount rate prescribed by OMB Circular A-94.

TABLE C-2

PRESENT VALUE OF $1 FLOWING UNIFORMLY
OVER THE STATED PERIOD

(Continuous Compounding)

Period	Annual Effective Discount Rate						
	2%	5%	8%	10%[a]	12%	15%	20%
1.	.9902	.9760	.9625	.9538	.9454	.9333	.9141
2.	.9707	.9295	.8912	.8671	.8441	.8115	.7618
3.	.9518	.8853	.8252	.7883	.7537	.7057	.6348
4.	.9331	.8431	.7641	.7166	.6729	.6136	.5290
5.	.9148	.8030	.7075	.6516	.6008	.5336	.4408
6.	.8968	.7647	.6551	.5922	.5365	.4640	.3674
7.	.8792	.7283	.6065	.5384	.4790	.4035	.3061
8.	.8620	.6936	.5616	.4895	.4277	.3508	.2551
9.	.8451	.6606	.5200	.4450	.3818	.3051	.2126
10.	.8285	.6291	.4815	.4045	.3409	.2653	.1772
11.	.8123	.5992	.4458	.3677	.3044	.2307	.1476
12.	.7964	.5706	.4128	.3343	.2718	.2006	.1230
13.	.7807	.5435	.3822	.3039	.2427	.1744	.1025
14.	.7654	.5176	.3539	.2763	.2167	.1517	.0854
15.	.7504	.4929	.3277	.2512	.1935	.1319	.0712
16.	.7357	.4695	.3034	.2283	.1727	.1147	.0593
17.	.7213	.4471	.2809	.2076	.1542	.0997	.0494
18.	.7071	.4258	.2601	.1887	.1377	.0867	.0412
19.	.6933	.4055	.2409	.1716	.1229	.0754	.0343
20.	.6797	.3862	.2230	.1560	.1098	.0656	.0286
21.	.6664	.3678	.2065	.1418	.0980	.0570	.0238
22.	.6533	.3503	.1912	.1289	.0875	.0496	.0199
23.	.6405	.3336	.1770	.1172	.0781	.0431	.0166
24.	.6279	.3178	.1639	.1065	.0698	.0375	.0138
25.	.6156	.3026	.1518	.0968	.0623	.0326	.0115
26.	.6035	.2882	.1405	.0880	.0556	.0284	.0096
27.	.5917	.2745	.1301	.0800	.0497	.0247	.0080
28.	.5801	.2614	.1205	.0728	.0443	.0214	.0067
29.	.5687	.2490	.1116	.0661	.0396	.0184	.0055
30.	.5676	.2409	.1033	.0601	.0353	.0162	.0046

[a] Discount rate prescribed by OMB Circular A-94.

TABLE C-3

PRESENT VALUE OF A UNIFORM SERIES OF $1 PAYMENTS FLOWING AT THE END OF EACH PERIOD

(Discrete Compounding)

	Annual Effective Discount Rate						
Period	2%	5%	8%	10%[a]	12%	15%	20%
1.	.980	.952	.926	.909	.893	.870	.833
2.	1.942	1.859	1.783	1.736	1.690	1.626	1.528
3.	2.844	2.723	2.577	2.487	2.402	2.283	2.106
4.	3.808	3.546	3.312	3.170	3.037	2.855	2.589
5.	4.713	4.329	3.993	3.791	3.605	3.352	2.991
6.	5.601	5.076	4.623	4.355	4.111	3.784	3.326
7.	6.472	5.786	5.206	4.868	4.564	4.160	3.605
8.	7.325	6.463	5.747	5.335	4.968	4.487	3.837
9.	8.162	7.108	6.247	5.759	5.328	4.772	4.031
10.	8.983	7.722	6.710	6.144	5.650	5.019	4.192
11.	9.787	8.306	7.139	6.495	5.938	5.234	4.327
12.	10.575	8.863	7.536	6.814	6.194	5.421	4.439
13.	11.348	9.394	7.904	7.103	6.424	5.583	4.533
14.	12.106	9.899	8.244	7.367	6.628	5.724	4.611
15.	12.849	10.380	8.559	7.606	6.811	5.847	4.675
16.	13.578	10.838	8.851	7.824	6.974	5.954	4.730
17.	14.292	11.274	9.122	8.022	7.120	6.047	4.775
18.	14.992	11.690	9.372	8.201	7.250	6.128	4.812
19.	15.678	12.085	9.604	8.365	7.366	6.198	4.844
20.	16.351	12.462	9.818	8.514	7.469	6.259	4.870
21.	17.011	12.821	10.017	8.649	7.562	6.312	4.891
22.	17.658	13.163	10.201	8.772	7.645	6.359	4.909
23.	18.292	13.489	10.371	8.883	7.718	6.399	4.925
24.	18.914	13.799	10.529	8.985	7.784	6.434	4.937
25.	19.523	14.094	10.675	9.077	7.843	6.464	4.948
26.	20.121	14.375	10.810	9.161	7.896	6.491	4.956
27.	20.707	14.643	10.935	9.237	7.943	6.514	4.964
28.	21.281	14.898	11.051	9.307	7.984	6.534	4.970
29.	21.844	15.141	11.158	9.370	8.022	6.551	4.975
30.	22.396	15.372	11.258	9.427	8.055	6.566	4.979

a/ Discount rate prescribed by OMB Circular A-94.

TABLE C-4

PRESENT VALUE OF A UNIFORM SERIES OF
$1 PAYMENTS FLOWING UNIFORMLY THROUGHOUT EACH PERIOD

(Continuous Compounding)

	Annual Effective Discount Rate						
Period	2%	5%	8%	10% a/	12%	15%	20%
1.	.990	.976	.962	.954	.945	.933	.914
2.	1.961	1.906	1.854	1.821	1.790	1.745	1.676
3.	2.913	2.791	2.679	2.609	2.543	2.450	2.311
4.	3.846	3.634	3.443	3.326	3.216	3.064	2.840
5.	4.760	4.437	4.150	3.977	3.817	3.598	3.281
6.	5.657	5.202	4.805	4.570	4.353	4.062	3.648
7.	6.536	5.930	5.412	5.108	4.832	4.465	3.954
8.	7.398	6.623	5.974	5.597	5.260	4.816	4.209
9.	8.244	7.284	6.494	6.042	5.642	5.121	4.422
10.	9.072	7.913	6.975	6.447	5.983	5.386	4.599
11.	9.884	8.512	7.421	6.815	6.287	5.617	4.747
12.	10.681	9.083	7.834	7.149	6.559	5.818	4.870
13.	11.461	9.627	8.216	7.453	6.802	5.992	4.972
14.	12.227	10.144	8.570	7.729	7.018	6.144	5.058
15.	12.977	10.637	8.897	7.980	7.212	6.276	5.129
16.	13.713	11.107	9.201	8.209	7.385	6.390	5.188
17.	14.434	11.554	9.482	8.416	7.539	6.490	5.238
18.	15.141	11.979	9.742	8.605	7.676	6.577	5.279
19.	15.835	12.385	9.983	8.777	7.779	6.652	5.313
20.	16.514	12.771	10.206	8.932	7.909	6.718	5.342
21.	17.181	13.139	10.412	9.074	8.007	6.775	5.366
22.	17.834	13.489	10.604	9.203	8.095	6.824	5.385
23.	18.475	13.823	10.781	9.320	8.173	6.868	5.402
24.	19.102	14.141	10.945	9.427	8.243	6.905	5.416
25.	19.718	14.443	11.096	9.524	8.305	6.938	5.427
26.	20.322	14.732	11.237	9.612	8.360	6.966	5.437
27.	20.913	15.006	11.367	9.692	8.410	6.991	5.445
28.	21.493	15.268	11.487	9.765	8.454	7.012	5.452
29.	22.062	15.517	11.599	9.831	8.494	7.031	5.457
30.	22.620	15.754	11.702	9.891	8.529	7.047	5.462

a/ Discount rate prescribed by OMB Circular A-94.

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